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The neural basis of Number and Person phi-features processing: An fMRI study in highly proficient bilinguals

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Abstract

No studies have investigated the neural correlates of Number and Person agreement processing in bilinguals. Because a previous fMRI study showed difference in L1 and L2 morphosyntactic processing of L1 Turkish–L2 Persian bilinguals, it was of interest whether this difference can be specifically attributed to Number or Person processing. Therefore, we reanalyzed these data at the whole-brain level, revealing a selective response for Number Violations in the pars opercularis (PO), whereas Number and Person Violations activated the posterior superior temporal gyrus (pSTG). These results support the decomposition of agreement projections and their neuroanatomical substrates in bilinguals and confirm the involvement of systematically different feature-checking and feature-mapping mechanisms in Number and Person agreement but shared mechanisms between L1 and L2. Moreover, at variance with previous reports, Number Violations evoked more effects than Person Violations in pSTG, suggesting qualitatively different processing underlying R-expression and pronominal controllers.

Introduction

In natural languages grammatical agreement signals the relations among sentence constituents; it depends on the interplay of syntactic, semantic and morphological aspects (Corbett, 1998; Pollard & Sag, 1994). In the Minimalist approach, Person, Number and Gender are represented as a feature set that, during agreement computation, is uniformly dealt with by the formal operation Agree (Chomsky, 2000, 2001), which is responsible for the movement of feature values from one element to another. In recent years numerous hypotheses have challenged the minimalist single-cluster approach to subject-verb agreement and highlighted the structural differentiation of the features involved in subject-verb agreements (Shlonsky, 2010; Sigurðsson, 2004; Sigurðsson & Holmberg, 2008). Many studies across different languages (i.e., Hebrew, Arabic, Icelandic, Italian) have also shown that separating the bundle of features involved in subject-verb agreement and analyzing each of them as separate projection explains the syntactic phenomenon of agreement in a way that captures the fact that not all languages show the same richness of agreement (Mancini, 2018). More specifically, the distinction between the Person feature and other phi-features is emphasized in the hypothesis of Agree versus Spec-Head Relationship (Den Dikken, 2019) and the theory of phi-features (Ackema & Neeleman, 2018, 2019).

Based on specificational copular sentences and long-distance agreement constructions, Den Dikken (2019) put forward two syntactic mechanisms for establishing phi-features agreements – namely, Agree and Spec-Head configurations which correspond to the operation Agree (Chomsky, 2000, 2001). The directionality of Agree is a much-debated issue. Despite arguments in favor of the downward (head-complement) Agree model (e.g., Adger, 2003; Merchant, 2011; Wurmbrand, 2012, 2014; Zeijlstra, 2012), the upward (Spec-Head) Agree model assumes that the valued features are being 'transmitted' upward within the syntactic structure (Preminger, 2013; Preminger & Polinsky, 2015). Finally, Bjorkman and Zeijlstra (2014) proposed a "hybrid" theory, according to which both standard 'downward' Agree and 'upward' Agree are possible options in the grammar.[1] Downward Agree copies a feature value from a goal c-commanded by the probe, whereas upward Agree copies a feature value from a goal m-commanded by the probe (Murphy & Puškar, 2018). More recently, Den Dikken (2019) argued that Number agreement is possible under both the Agree and the Spec-Head relation; whereas Person agreement cannot transpire under (downward) Agree, being establishable only in a Spec-Head configuration. Den Dikken (2019) concluded that there is a key difference between the feature-checking processes involved in Number and Person agreement. Using #-over-π structure[2], Den Dikken (2019: 6-7) discussed that the clausal π-head cannot serve as a probe in (downward) Agree relations, as illustrated in the clausal spine (1):

(1) $[_{CP}\ C\ [_{\#P}\ \#\ _{\{IND\}}\ [_{\pi P}\ \pi\ _{\{PART\}}\ (\ldots)\ [_{VP}\ V\ _{\{IND,PART\}}]]]]$[3]

In the clause (1), the finite verb shows agreement with the subject for Number and Person. The Person and Number, which serve as probes in the clausal agreement system, adorned with unvalued feature [*u*PART] and [*u*IND], respectively. The πP of the subject pronoun is not directly accessible to the clausal π-head because it occupies the specifier position of the subject, which is itself a specifier. Also, no outside probe can by itself reach into the innards of a specifier. Hence, the clausal π-head cannot directly target the πP inside the subject nor the entire subject pronoun (i.e., #P) because #P, specified for [IND] but not for [PART], is not a match for the π-head's [*u*PART] feature. Therefore, Person agreement cannot happen under (downward) Agree. But the higher #-head can Agree with and attract the pronominal #P, provided that clausal π-head raises to #. Then, the clausal #-head can probe the entire subject pronoun, #P, and attract it to its specifier, which results in a Spec-Head relation between the clausal #-head and the pronominal subject. This Spec-Head relation involves not just Number but Person as well.

Likewise, the theory of phi-features (Ackema & Neeleman, 2018, 2019) has proposed two core hypotheses for Number and Person agreements. One, R-expressions[4] do not have Person, while pronouns do. Two, all Persons have a Person feature. By contrast, singular is the absence of a Number feature. Accordingly, this account which is based on the evidence of Zawiszewski et al. (2016) and Mancini et al. (2017) (among others) proposes two generalizations when the verb carries incorrect agreement. First, in EEG studies, in sentences with R-expression subjects, Person behaves differently from Number in Violation detection with a more costly repair phase than Number. Second, in sentences with pronominal subjects, Person behaves like Number in Violation detection but with a more costly repair than Number. A repair phase follows after a correct diagnosis of the anomaly (Barber & Carreiras, 2005; Carreiras et al., 2004; Friederici et al., 2002; Hagoort & Brown, 2000; Molinaro et al., 2008) and its costs depend on the nature of the feature that is being violated (see also Mancini, 2018). In fMRI context, these two generalizations have adapted as follows (Ackema & Neeleman, 2019: 8). In sentences with R-expressions as subject, Person behaves qualitatively differently from Number and will have a quantitatively larger effect. In sentences with pronouns as subject, there are no qualitative differences between Person and Number, but Person will have a quantitatively larger effect. According to the predictions of Ackema and Neeleman (2019), more costs or larger effects for Person Violations than Number Violations seems to be independent of the nature of the subject. The account of Ackema and Neeleman (2019), however, does not seem to address the case where specific controllers as subject are used for Number and Person Violations; that is to say, R-expressions for Number Violations and pronouns for Person Violations as schematized in (2). The main advantage of this case is that it can shed more light on the nature of the subject (i.e., the R-expression and the pronoun) whilst each kind of violation (whether a Number Violation or Person Violation) contains a clash in the feature specification. Namely, on the one hand, there is a clash between the Number specification of the subject and the Number specification of the verb; and on the other hand, there is a clash between the Person specification of the subject and the Person specification of the verb.

(2) a. R-expression$_{3SG}$ ….. V_{3PL} (Number Violation)
b. Pronoun$_{3SG}$ ….. V_{3PL} (Person Violation)

Using this paradigm, given that there is a clash in each Violation type, the prediction is that there should be a quantitative differences between Number and Person features similar to the reports of Zawiszewski et al. (2016) and Mancini et al. (2017), which found feature-specific costs or effect sizes. Also, a contrast is predicted between the R-expression and the pronoun, which may give rise to the involvement of different brain regions during processing of different features. Here, we explored this case in bilinguals by using an alternating language switching paradigm.

Now, the question arises whether the theoretical dissociation between Number and Person features corresponds to actual functions of the brain. If any of the theoretical frameworks laid out above is correct, neuroanatomically distinct mechanisms might correlate with Number and Person features. First, according to the theory of Den Dikken (2019) a feature-checking mechanism should control Number and Person consistency between trigger (subject) and target (verb) and second, according to the postulations of Mancini et al. (2017), a feature-mapping mechanism should align morphosyntactic information with semantic-discourse information. Integrating incoming information with previously encountered elements requires checking and mapping mechanisms enabling the interpretation of the overall agreement dependencies (Mancini, 2018). In monolingual contexts, in an ERP study using Basque sentences with Pronouns as subject and Number, Person and double (Number + Person) agreement Violations, Zawiszewski et al. (2016) found no differences between Person and Person + Number Violations in the P600 component, while both Person and Person + Number Violations elicited a larger P600 than Number Violations over posterior sites accompanied by a larger negativity over frontocentral sites. Therefore, the authors claimed qualitatively similar but quantitatively larger ERP signatures for Person as compared to Number Violations. In an fMRI study using Spanish sentences with R-expression as subject by Mancini et al. (2017), the anterior portion of the left middle temporal gyrus (LMTG) showed a selective response for Person Violations, whereas the posterior portion of this region was sensitive to both Person and Number Violations, with a greater response for Person compared to Number. The authors postulated two different mechanisms involved in agreement phenomena, which they call 'feature-checking' and 'feature-mapping.' They argued that Number and Person agreement involve a common feature-checking mechanism but differ in their feature-mapping options, with Number mapping to cardinality and Person to the discourse.

Despite extensive research on bilingualism, which factor most influentially modulates the brain plasticity in bilinguals remains an open question. Recent trends in the neuroscience of bilingualism have suggested that bilingualism should be modeled as a gradual rather than an all-or-none phenomenon (Luk & Bialystok, 2013; Gullifer et al., 2018; Dash et al., 2019; DeLuca et al., 2019; Surrain & Luk, 2019; Gullifer & Titone, 2020; Fedeli et al., 2021; Sulpizio et al., 2020; Pliatsikas et al., 2020). That is, seeing that the effects of L2 Age of Acquisition (AoA) depend on L2 experiences (Luk & Bialystok, 2013; Gullifer et al., 2018), bilingual experience should be defined as a spectrum of the experience-based dynamic process consisting of three

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primary features of L2 AoA, L2 proficiency and L1/L2 usage (Luk & Bialystok, 2013; Sulpizio et al., 2020). Investigating resting-state functional connectivity (FC), for instance, Sulpizio et al. (2020) observed increased connectivity in language networks in late high-proficient versus early high-proficient bilinguals. Another important factor that can modulate L2 processing is the grammatical similarity between the native and the nonnative language. It was shown that differences between native and nonnative languages are obtained only when morphological categories differ between L1 and L2 (Díaz et al., 2016; Zawiszewski & Laka, 2020). This is in line with the study of Hartsuiker et al. (2004) who suggested that grammatical traits shared by two languages increase the efficiency of code-switching between languages. In the present study, bilingual speakers had high proficiency in both Turkish (L1) and Persian (L2) and used both languages regularly. They were exposed to mainly Turkish at home and started to learn Persian around the age of 7 when they entered primary school. We investigated Turkish–Persian bilinguals in terms of morphosyntactic processing. Turkish and Persian belong to the Altaic and Indo-Iranian subdivisions of the Indo-European language family, respectively, but share unmarked subject-object-verb (SOV) word orders (Comrie, 2009) and certain syntactic features, such as verbal agreements. Subject-verb agreement in Turkish and Persian entails the analysis of two phi-features – namely, Person and Number. Thus, in both languages, verbs obligatorily agree in Person and Number with animate subjects, have six grammatical Persons and are inflected for three singular and three plural Persons. Based on the unified competition model (UCM; MacWhinney, 2005), the mechanisms of L1 learning are seen as a subset of the mechanisms of L2 learning. In particular, whenever a surface structure, such as morphosyntax, is shared, the mechanisms used in L1 will be transferred to process L2 (Roncaglia-Denissen & Kotz, 2016).

To our knowledge, there is only one study that has directly addressed phi-features processing in bilinguals. Using online EEG technique and L1 materials, Martínez de la Hidalga et al. (2019) investigated early, high-proficient L1 Basque–L2 Spanish bilinguals during processing phi-features (Person/Number). Their results revealed that in the acceptability task bilinguals reacted faster and more accurately to Person than Number Violations. In the ERP experiment, however, Person violations generated larger 300-400 ms-negativities and larger 400-700 ms-positivities than Number violations. Overall, bilingual speakers processed Person and Number features separately, the Person being far more salient than the Number. Later, Martínez de la Hidalga et al. (2021) examined whether native-like processing can be achieved in a second language. Using ERP recordings and high-proficient L1 Basque–L2 Spanish bilinguals but presenting L2 materials, these authors found that these early and proficient non-native speakers were indistinguishable from native speakers not only in the acceptability task but also in the ERPs. They concluded that native and non-native speakers have a tendency to generate larger negativity for Person than for Number. One major difference between our work and the work of Martínez de la Hidalga et al. (2019, 2021) is that we used R-expressions for Number Violations and Pronouns for Person Violations, but they focused on the Pronouns for both Number and Person Violations. Another major difference is that we presented the L1 and L2 materials simultaneously to our participants. Moreover, the present study explored the neural correlates of phi-features processing in Turkish and Persian languages with a typologically nominative-accusative pattern. Given that the literature has shown distinct neurocognitive mechanisms for processing agreement with transitive (ergative-marked) versus intransitive subjects (absolutive-marked) (Chow et al., 2018), we expected different results compared to Martínez de la Hidalga et al. (2021).

It is well-established that for syntactic processing a left-lateralized network comprising posterior temporal and inferior frontal regions is crucial. The posterior part of the IFG (pIFG; pars opercularis (PO), BA 44) appears to be specialized strictly for syntactic processing (Friederici et al., 2017; Goucha & Friederici, 2015; Zaccarella et al., 2017), which is connected to the temporal cortex by a fiber bundle. This dorsal fronto-temporal network, consisting of pars opercularis (PO) and posterior superior temporal gyrus (pSTG), subserves the mastery of hierarchically complex sentences (Friederici et al., 2017; Friederici, 2018; Vigneau et al., 2006). However, no information is available about which specific morphosyntactic mechanisms are supported by this fronto-temporal network. In a recent fMRI study the present authors found that morphosyntactic processing of sentences, alternating between L1 and L2, by highly proficient Turkish–Persian bilinguals, engaged a fronto-temporal network (Meykadeh et al., 2021a). Presenting morphosyntactically correct and Person/Number feature agreement violations, we found that grammaticality effects were stronger in L1 than in L2 in the PO region, whereas the reverse held for the pSTG, where activation dominated for L2. We suggested that the pars opercularis is involved in activating the language in focus; perhaps surprisingly, this appeared to be more demanding for L1 sentences, which may have to be reactivated from its comparatively strong suppression during the preceding L2 sentences. In association with this idea, more recently, Román and Gómez-Gómez (2022) carried out a systematic review and argued that the native language is dominant in late bilinguals and L2 usage is expected to trigger inhibitory processes to facilitate retrieval of the weaker L2 representations. When bilinguals try to retrieve their L1 later, it takes time to access the suppressed representations in the L1. Reanalyzing our recent data (Meykadeh et al., 2021a), we investigated whether these two regions differ functionally in managing Number and Person features in bilinguals, given that these features convey different types of information.

The present reanalysis has three major objectives. The first goal is to test the hypothesis of Agree versus Spec-Head Relationship (Den Dikken, 2019), which postulates that the feature-checking of Number and Person are established under different configurations (Agree or Spec-Head), on the level of neuroanatomical correlates. The second objective is to investigate the postulate of Mancini et al. (2017) that distinct feature-mapping mechanisms are involved during Number and Person processing, with Number mapping to cardinality and Person to the discourse. In the light of the theory of phi-features (Ackema & Neeleman, 2013, 2018, 2019) that predicts qualitative and quantitative differences between Number and Person features, we checked specific controllers for Number and Person Violations in order to better understand the nature of subject. Accordingly, we hypothesized qualitatively and quantitatively different processing of Number and Person features. Lastly, this reanalysis addresses the question whether highly proficient bilinguals with L2 AoA at age 7 differently process phi-features in their L1 and L2.

Methods

Participants

A total of 41 right-handed (Oldfield, 1971) Turkish–Persian bilinguals, reporting normal hearing, were recruited among university students. The data of five participants were excluded from the analysis due to aliasing and excessive movement artifacts. Therefore, the final sample consisted of 36 participants (21 female, mean age = 27.4, range = 22-34 years; mean years of education = 19.5 years). Participants were all native speakers of Turkish, born into and raised in Turkish-speaking families, mostly lived in Turkish-speaking Iranian provinces and had learned Persian at school from the age of seven. For all participants, Persian was the principal language they had been using and still used during their education. To quantify the language proficiency levels of bilinguals, behavioral measurements were used because there were no standardized language proficiency tests for Turkish or Persian. We assessed the degree of L2 proficiency of our participants behaviourally in comparison to a group of native speakers of Persian (described in Meykadeh et al., 2021b). Regarding Persian language competence, our bilingual speakers were indistinguishable from monolingual speakers in terms of performance and neural signals of morphosyntactic violations (Meykadeh et al., 2021b, for more details), providing evidence that all bilinguals should be classified as highly proficient in Persian language. Furthermore, our sample was stratified in terms of language dominance. The bilinguals' dominance configurations between two languages were assessed via the Bilingual Dominance Scale (BDS) that was developed and empirically validated by Dunn and Fox Tree (2009). The BDS generates dominance scores for each language on an interval scale. Bilingual participants did not show any significant difference between Turkish and Persian on the language dominance. Additionally, the present bilingual population showed a strong overlap of neural networks for L1 and L2, suggesting structural similarities of neuroanatomical organization (see Meykadeh et al., 2021a, for more details). Taken together, all these findings indicate that the current bilinguals were balanced in their two languages. Therefore, native-like morphosyntax processing of our bilingual population motivated the design of the present study. Written informed consent was obtained from each participant in accordance with the guidelines of the Helsinki regulations; the study was approved by the Research Ethical Committee of Iran University of Medical Sciences (IR.IUMS.REC.1398.465).

Materials

In the study reported by Meykadeh et al. (2021a), 128 auditory sentences (50% in Turkish – as L1 – and 50% in Persian – as L2) were used. Half the sentences in each language were morphosyntactically consistent, whereas the others were incorrect. Incorrect sentences were not derived from correct ones, as it was done in Meykadeh (2021) and Meykadeh et al. (2021a). The sentences were created separately for each language. Thus, in the present study the materials per language contained 64 sentences, consisting of sixteen sentences each with Number Correct, Person Correct, Number Violations and Person Violations. To be noted, only single-feature Violations for Number and Person conditions in each language were used, no double Violations. In the Correct conditions, the Number and Person stimuli differed (i) in the subject type (the former contained R-expression as subject and the latter contained Pronoun as subject) and (ii) in the person feature (3rd person for Number feature and 1st person for Person feature), there was no difference in plurality/singularity because we used a set of singular (50%) and plural (50%) subjects for all conditions (regardless of the feature manipulated) as framed in (3):

(3) R-expression$_{3SG}$ ….. V_{3PL} (Number Violation)
R-expression$_{3PL}$ ….. V_{3SG} (Number Violation)
Pronoun$_{1SG}$ ….. V_{3SG} (Person Violation)
Pronoun$_{1PL}$ ….. V_{3PL} (Person Violation)

The only difference between Violation conditions and Correct conditions is that the former involves a clash either in the Number feature or in the Person feature. The Number Violations contained a 3rd Person singular subject followed by a 3rd Person plural verb or a 3rd Person plural subject followed by a 3rd Person singular verb. Because R-expressions are Personless (Ackema & Neeleman, 2019), we used only R-expression for subjects in Number Violation and Number Correct conditions. The Person Violations also contained a 1st Person singular subject followed by a 3rd Person singular verb or 1st Person plural subject followed by a 3rd Person plural verb. Because pronouns are specified for Person (Ackema & Neeleman, 2019), we used only pronouns for subjects in Person Violations and Person Correct conditions. Correct conditions presented 1st Person singular, 1st Person plural, 3rd Person singular and 3rd Person plural subject followed by 1rd Person singular, 1rd Person plural, 3rd Person singular and 3rd Person plural verb respectively, as illustrated in Table S1 (Supplementary Materials). For further details please see the original reports (Meykadeh et al., 2021a) (see a detailed list of stimulus sentences for each language type in Appendix S1, Supplementary Materials).

Procedure

The participants underwent event-related functional magnetic resonance imaging (ER-fMRI) while performing a Number/Person phi-features agreement task, including four alternating rest and auditory sentence blocks. Each auditory sentence block consisted of 32 runs and was preceded and followed by 30-s resting periods during which no stimuli were presented, providing hemodynamic baseline data (318 s per block). Within each block correct and incorrect sentences were randomly intermixed, but language blocks alternated in a fixed sequence (e.g., L1, L2, L1, L2 …). All sentences were spoken and recorded for auditory presentation. Each run contained three phases, a 1-s beep sound, a 3-s sentence presentation and a response phase of 4-, 5-, or 6-s ($M = 5$ s). Stimuli were presented via headphones using MATLAB's Psychtoolbox. A black cross for fixation remained on the screen for the entire duration of the recording, with the exception of 30-s resting periods between blocks during which a blank screen was presented to allow participants to move their eyes freely and blink if needed. Participants were instructed to respond by pressing the button of a left (Violation) or right (Correct) response grip with the thumb. A more detailed description of the experimental design can be found in Meykadeh et al. (2021a).

MRI Data Acquisition

Functional T2*-weighted EPI-BOLD MRI data were obtained on a 3.0 Tesla Siemens Prisma MRI Scanner at National Brain Mapping Laboratory (NBML), using a sequential slice acquisition EPI sequence (TE: 30 ms, TR: 3000 ms, flip angle: 90°, slice thickness: 3 mm, voxel size: 3×3×3 mm, matrix size: 64×64, FOV: 192 mm^2, slice gap: 0 mm) with a 20-channel head coil and a functional scanning time of 1290 s and 430 volumes. Each volume was composed of 45 axial slices. Structural images were acquired with a T1-weighted sequence, using a 3D inversion-recovery gradient-echo (MP-RAGE) sequence (TE: 3.53 ms, TR: 1800 ms, flip angle: 7°, slice thickness: 1 mm, voxel size: 1×1×1 mm, matrix size: 256×256, FOV: 256 mm^2, slice gap: 0 mm, duration: 5 min).

Data preprocessing

Functional data were analyzed using FEAT (fMRI Expert Analysis Tool) Version 6.00, part of FSL (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl). Preprocessing included standard processes for motion correction using MCFLIRT (Jenkinson et al., 2002); slice-timing correction using Fourier-space time-series phase-shifting; non-brain removal using BET (Smith, 2002); spatial smoothing using a Gaussian kernel of FWHM 6.0 mm; multiplicative mean intensity normalization of the volume at each time point; high pass temporal filtering (Gaussian-weighted least-squares straight line fitting, with sigma = 50.0 s). Exploratory ICA-based data analysis was carried out using MELODIC (Beckmann & Smith, 2004) to remove unexpected artefacts or activation. Statistical analyses of fMRI data were conducted using general linear modeling (GLM), as implemented in FSL. First-level analyses included one non-experimental (i.e., beep sound and incorrect responses) and eight experimental conditions modeled with separate regressors: Extra, TNC, TPC, TNV, TPV, PNC, PPC, PNV and PPV[5]. Specific contrasts of interest were computed for each individual and combined into whole brain group-level analyses. These contrasts included: (i) TNV vs. TNC; (ii) TPV vs. TPC; (iii) PNV vs. PNC; (iv) PPV vs. PPC; (v) TNV vs. TPV; (vi) TPV vs. TNV; (vii) PNV vs. PPV; (viii) PPV vs. PNV; (ix) TNV vs. PNV and (x) TPV vs. PPV. Z (Gaussianised T/F) statistic images were thresholded using clusters determined by $Z > 3.1$ and a (corrected) cluster significance threshold of $P < 0.05$.

Whole-Brain analysis

To untangle the probable mechanisms involved in Number/Person phi-features agreement, a whole-brain analysis was performed. Its findings were consistent with our previous analysis (Meykadeh et al., 2021a), showing the activation of a dorsal frontotemporal network (including the left PO and pSTG), which have been established to be specialized for syntactic processing (Friederici et al., 2017). In the whole-brain analysis, we observed the sensitivity of the PO only to Number Violations, whereas the pSTG was activated for Number Violations as well as for Number Correct, Person Correct and Person Violation conditions relative to the pre-sentence baseline (see Figure 1 and Table S2; Supplementary Materials). With the exception of the Person Violation (activated only for L1), this activation pattern was similar for L1 and L2 in pSTG. Z-statistic images were thresholded using clusters determined by $Z > 3.1$ and a (corrected) cluster significance threshold of $P < 0.05$. All local maxima are reported as MNI coordinates.

ROI analysis

Based on the whole-brain analysis, a ROI analysis on the Number and Person phi-features data was performed in which two regions were tested using the FSL's Featquery tool. Particularly, to uncover the mechanisms involved in processing phi-features agreements, the PO and the pSTG were defined for the Number/Person Violations and Number/Person Correct agreement and percent signal change (PSC) was calculated, for each participant and region of interest (ROI) as intensity measure according to the Harvard-Oxford Atlas as implemented in FSL. To isolate the neural network involved in deciphering and constructing grammatical consistency, we performed a direct contrast between Correct and Violation conditions per feature, language type and

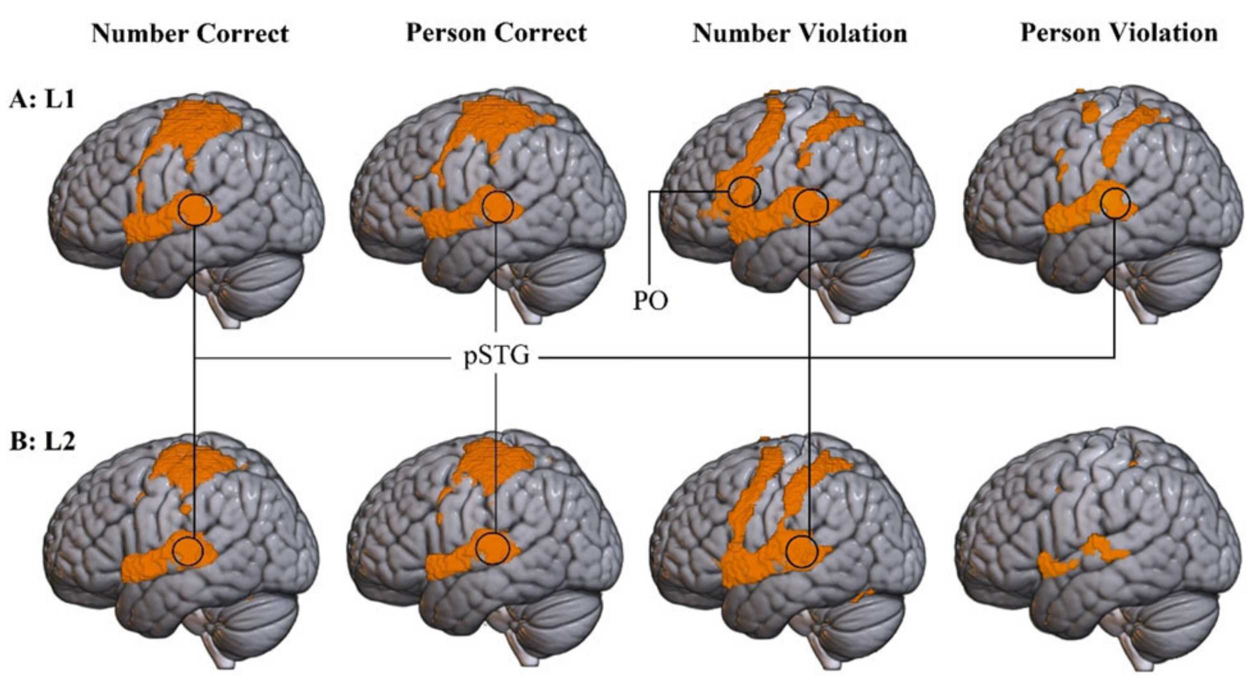

Figure 1. Whole-brain clusters (orange) of BOLD activation for (**A**) L1 and (**B**) L2 sentences, projected onto surface templates using MRIcroGL software in four experimental conditions including (from left to right) Number Correct, Person Correct, Number Violation and Person Violation relative to the baseline. Black circles represent regions in the frontotemporal network where significant activations were found for Number Correct, Person Correct and Number Violation and Person Violation (whole-brain maps are displayed at threshold $Z \geq 3.1$).

ROI. To uncover the quantitative differences between Number and Person Violations per candidate involved in the establishment of form-to-meaning mapping, a direct contrast was also performed between Number and Person Violations per language type, as proposed by Mancini et al. (2017). Intensity was set as dependent variable, while Grammaticality and Language type were independent variables. All statistical analyses were performed using SPSS v26 (IBM Corporation, Armonk, NY). The effects of interest for intensity at each ROI were analyzed with repeated measures analysis of variance (ANOVA) on factors Language type (L1 = Turkish, L2 = Persian), Grammaticality (Correct vs. Violation) and Feature (Number vs. Person). To control for multiple comparisons, Bonferroni correction was applied ($\alpha/2 = 0.025$ for omnibus ANOVAs and $\alpha/2 = 0.025$, $\alpha/4 = 0.012$, $\alpha/8 = 0.0062$ for Post hoc t-tests) and only significant results are reported.

Behavioural data analysis

Behavioural data analysis was conducted separately for the dependent variables 'Response Accuracy' (RA) and 'Response Time' (RT) which were recorded for all trials. Only trials in which the participants responded accurately were included in the RT analysis. RA and RT data were submitted separately to $2 \times 2 \times 2$ repeated-measurement ANOVAs with factors Grammaticality (Violation vs. Correct), Language (L1 vs. L2) and Feature (Number vs Person). Post-hoc pairwise comparisons were adjusted for multiple comparisons using the Bonferroni method. For Post-hoc t-test, critical alpha was set to 0.006.

Results

Behaviour

The results of the response time data in Table S3 (Supplementary Materials) revealed slower responses to L1 than L2 trials (977.77 vs. 883.6 ms), denoting reversed language dominance effects, which have been attributed to proactive inhibitory control of the dominant language or adaptation of language-specific selection thresholds (Declerck et al., 2020).

The main effect of Grammaticality ($F(1,35) = 9.55$, $p = 0.004$, $\eta_p^2 = 0.210$) indicates that participants responded significantly faster to overall grammatical sentences (893.60 ms) than their ungrammatical counterparts (967.57 ms). The significant main effect of Feature ($F(1,35) = 21.17$, $p < 0.001$, $\eta_p^2 = 0.370$) reveals that participants reacted significantly faster to sentences containing Person feature (887.14 ms) than Number feature (974.04 ms). The significant main effect of Language ($F(1,35) = 19.05$, $p < 0.001$, $\eta_p^2 = 0.346$) shows that participants had significantly faster responses to L2 sentences (883.37 ms) than to L1 sentences (977.81).

A significant Grammaticality × Language interaction ($F(1,35) = 4.73$, $p = 0.036$, $\eta_p^2 = 0.116$) indicated that in L1 participants reacted faster to grammatical sentences (922.57 ms) than to ungrammatical sentences (1033.04 ms) (t (35) = -3.775, p = 0.001), whereas in L2 there were no differences between grammatical (864.64 ms) and ungrammatical (902.10 ms) sentences (t (35) = -1.289, p = 0.208). A significant Grammaticality × Feature interaction ($F(1,35) = 56.01$, $p < 0.001$, $\eta_p^2 = 0.609$) was due to substantially shorter reaction times to grammatical sentences (870.11 ms) than to ungrammatical sentences (1077.97 ms) containing Number feature (t (35) = -6.506, p < 0.001), but there was no significant difference between grammatical (917.10 ms) and ungrammatical (857.18 ms) sentences containing Person feature (t (35) = 2.166, p = 0.037). A significant Language × Feature interaction ($F(1,35) = 5.92$, $p = 0.020$, $\eta_p^2 = 0.141$) indicated that in L1 participants reacted faster to sentences containing Person feature (922.07 ms) than to sentences containing Number feature (1033.54 ms) (t (35) = -4.877, p < 0.001), and similarly in L2 participants responded faster to sentences containing Person feature (852.20 ms) than to sentences containing Number feature (914.54 ms) (t (35) = -3.128, p = 0.003).

Ultimately, a triple Grammaticality × Language × Feature interaction ($F(1,35) = 7.706$, $p = 0.009$, $\eta_p^2 = 0.176$) turned out to be significant. The analysis by Grammaticality factor showed that in L1 the grammatical Number condition (898.24 ms) was recognized faster than the ungrammatical Number condition (1168.84 ms) (t (35) = -6.872, p < 0.001), but there were no differences between ungrammatical (897.25 ms) and grammatical (946.91 ms) sentences containing Person feature (t (35) = -1.544, p = 0.131). In L2, participants were significantly faster for grammatical sentences containing Number feature (841.99 ms) than for ungrammatical sentences containing Number feature (987.09 ms) (t (35) = -4.115, p < 0.001), but there were no differences between ungrammatical (817.11 ms) and grammatical (887.29 ms) sentences containing Person feature (t (35) = -2.003, p = 0.053). The analysis by Language factor showed that no differences were obtained for grammatical L1 and L2 sentences containing Person feature (946.91 vs. 887.29 ms) (t (35) = 1.705, p = 0.097), nor for sentences containing Number feature (898.24 vs. 841.99 ms) (t (35) = 1.782, p = 0.083). In ungrammatical conditions containing Person feature, participants were significantly faster for L2 (817.11 ms) than for L1 sentences (897.25 ms) (t (35) = 3.208, p = 0.003) and, similarly, in ungrammatical conditions containing Number feature, they were faster for L2 (987.10 ms) than for L1 sentences (1168.84 ms) (t (35) = -5.981, p < 0.001). The analysis by feature factor revealed no differences between Number and Person features in grammatical L1 sentences (898.24 vs. 946.91 ms) (t (35) = -2.449, p = 0.019), nor between Number and Person features in grammatical L2 sentences (841.99 vs. 887.29 ms) (t (35) = -1.871, p = 0.069). In ungrammatical L1 sentences, participants were significantly faster with Person than Number features (897.25 vs. 1168.84 ms) (t (35) = -6.969, p < 0.001) and, similarly, in ungrammatical L2 sentences, they were faster for Person than for Number features (817.11 vs. 987.09 ms) (t (35) = -5.450, p < 0.001).

Regarding response accuracy (RA), participants showed high accuracy in grammaticality judgments in both languages (mean accuracy of 98.52%, $SD = 3.20$; see Table S3; Supplementary Materials). The analysis of RA showed a main effect of Grammaticality ($F(1,35) = 5.084$, $p = 0.031$, $\eta_p^2 = 0.127$), indicating that participants were significantly more accurate for grammatical sentences (99.00%) than for their ungrammatical counterparts (98.05%). A significant main effect of Language ($F(1,35) = 9.09$, $p = 0.005$, $\eta_p^2 = 0.206$) indicated that participants were more accurate with L2 compared to L1 sentences (99.22% vs. 97.83%). A significant main effect of Feature ($F(1,35) = 11.518$, $p = 0.002$, $\eta_p^2 = 0.248$) also revealed that participants were more accurate for conditions containing Person feature than Number feature (99.35% vs. 97.70%) (t (35) = 3.394, p = 0.002). A significant Grammaticality × Feature interaction ($F(1,35) = 9.032$, $p = 0.005$, $\eta_p^2 = 0.205$) showed that participants were significantly less accurate for ungrammatical than grammatical sentences containing Number feature (96.70% vs. 98.70%) (t (35) = -2.873, p = 0.007), whereas there were no differences between ungrammatical and grammatical sentences containing Person feature (99.39% vs. 99.30%) (t (35) = 0.255, p = 0.800). A significant Language × Feature interaction ($F(1,35) = 8.737$, $p = 0.006$, $\eta_p^2 = 0.200$) showed that participants were more accurate for L2 than L1 sentences containing Number feature (98.96 vs. 96.44) (t (35) = 3.245, p = 0.003), whereas no differences were found between L2 and L1 sentences containing Person feature (99.48 vs. 99.22) (t (35) = 0.770, p = 0.446). This finding replicates the one observed in the analysis of RTs (see Figure 2B).

Significant main effects and interactions (see also Figure 2A) suggests that there might be different patterns of BOLD activity for each feature in each language. Furthermore, the RTs of the Grammaticality effect was significant for Number but not for Person feature (in both languages), which has not been reported previously. More categorically, the RTs of the Grammaticality effect (Violation minus Correct conditions) for Number feature was significantly larger in L1 than in L2 ($t_{(35)} = 3.233$, $p = 0.003$; $M = 270.60$ vs. 145.10 ms) (see Figure 2A).

Whole brain analysis

Grammaticality effect

The result of the Violation > Correct contrast per feature and language is listed in Table S4 (Supplementary Materials). In L1 the Number Violation conditions activated the pars opercularis significantly more than the Number Correct conditions. All other contrasts (Number Violation > Number Correct in L2, Person Violation > Person Correct in L2 and Person Violation > Person Correct in L1) yielded no significant results in the PO nor in the pSTG.

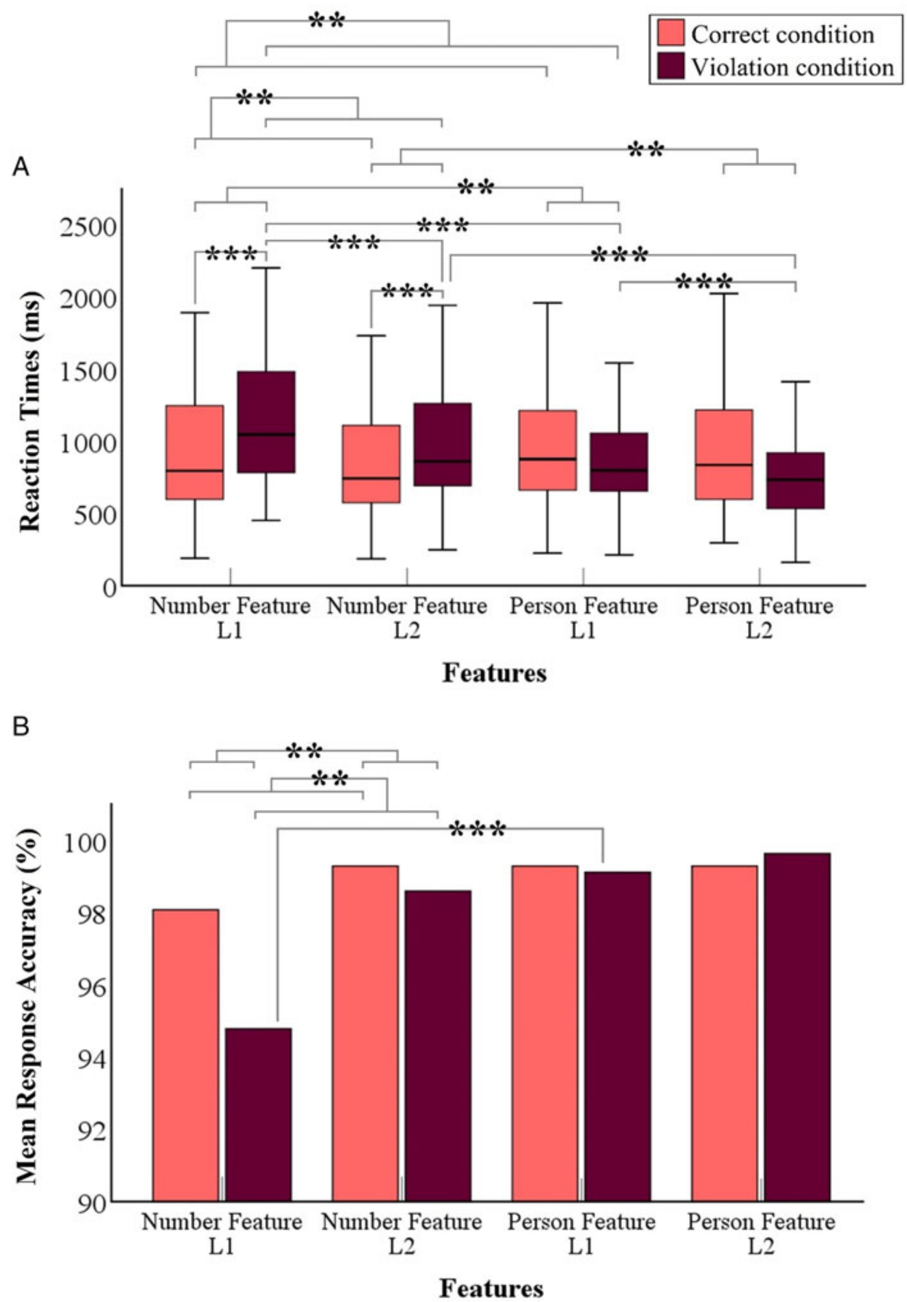

Figure 2. Behavioral results. Box plots of (**A**) mean Reaction Times and (**B**) mean Response Accuracy for Correct and Violation conditions per Language and Feature in milliseconds as well as the interaction of RTs and RAs between Features and Language. Significant effects are indicated by asterisks (Post-hoc ANOVA, $p < 0.006$, Bonferroni-corrected).

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Feature effect

The results of the contrast Number Violation > Person Violation per language type are listed in Table S4 (Supplementary Materials). Number Violation conditions showed more consistent activation than Person Violation conditions in both L1 and L2. Significant results of Number Violation > Person Violation contrast for L1 were obtained in the PO and pSTG. But for L2, only the PO showed significant results for Number Violation > Person Violation contrast.

Language effect. The results of the contrast L1 > L2 per Violation Feature are presented in Table S4 (Supplementary Materials). The L1 > L2 Number Violation contrast was significant in the pSTG, whereas the L1 > L2 Person Violation contrast was significant in the pSTG (see Figure 3 for a depiction of the significant contrasts).

ROI analyses

Grammaticality effects per feature, language and ROI are shown in Table 1 and Figure 4. Moreover, the direct contrasts between Number/Person Correct and Number/Person Violation conditions (as suggested by Mancini et al., 2017) per language are presented in Table 1 and Figure 4.

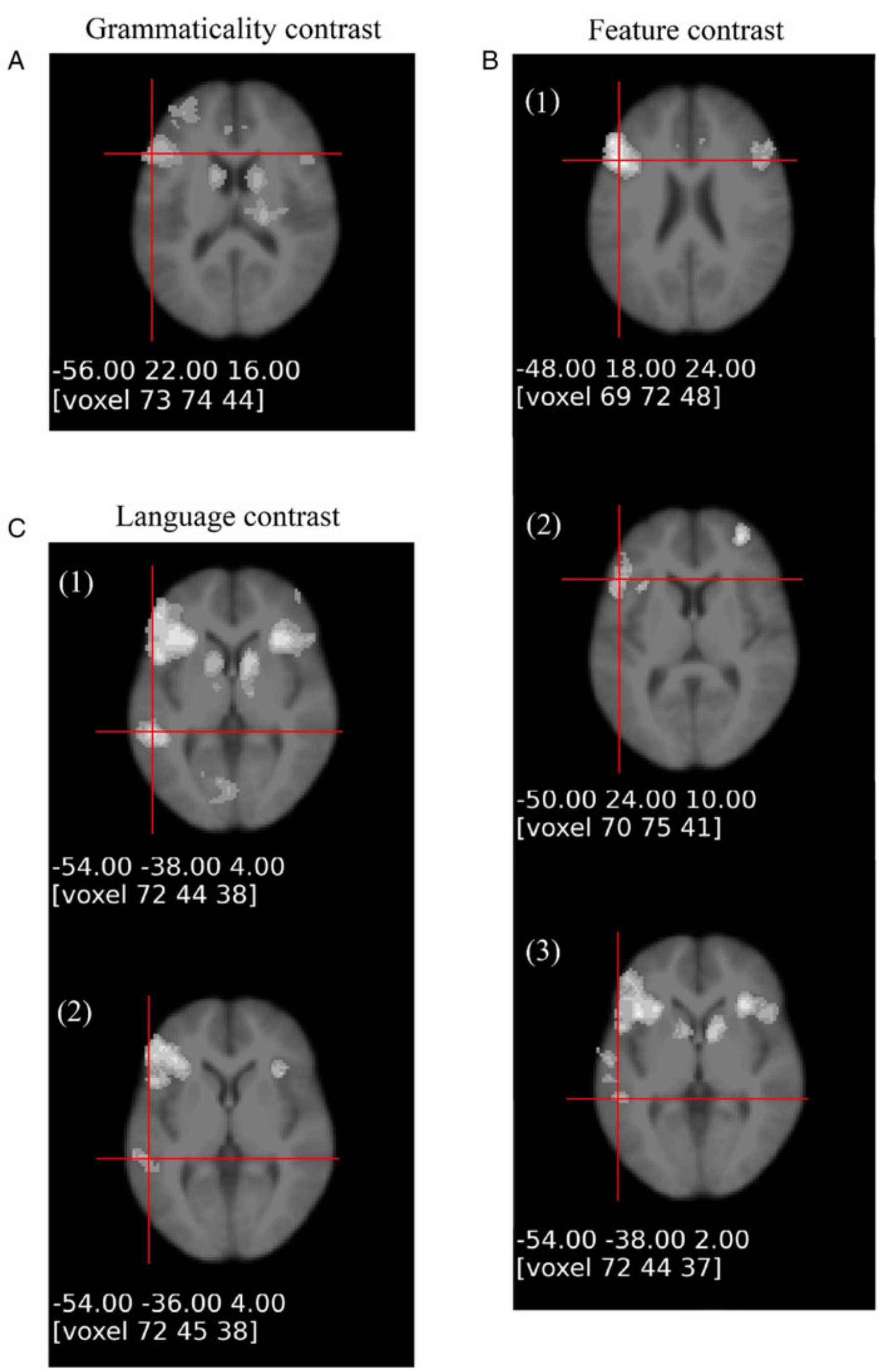

Figure 3. The axial view of whole-brain analysis. (**A**) Grammaticality contrast: Number Violation > Number Correct contrast in the region of PO for L1; (**B**) Feature contrast: (**B1**) Number > Person Violation contrast in the region of PO for L1; (**B2**) Number > Person Violation contrast in the region of PO for L2 and (**B3**) Number > Person Violation contrast in the region of pSTG for L1. (**C**) Language contrast: (**C1**) L1 > L2 Number Violation contrast in the region of pSTG and (**C2**) L1 > L2 Person Violation contrast in the region of pSTG. Data were obtained from cluster-based thresholding using an initial threshold of $Z > 3.1$ and corrected significance level of $p < 0.05$. Crosshairs represent the locations of significant contrasts in the PO and pSTG.

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Table 1. Summary of the Paired Samples *t* Test results for Grammaticality contrast per Language and Feature, and results of the contrast between Violation conditions across Languages.

Region	Contrast	Mean PSC (SD)	*t*-value	Sig. (2-tailed)
PO	TNV > TNC	0.489 (0.72)	4.087	**0.0002**
	TPV > TPC	0.110 (0.71)	0.926	0.361
	PNV > PNC	0.089 (0.61)	0.882	0.384
	PPV > PPC	-0.087 (0.57)	-0.911	0.368
	TNV > TPV	0.237 (0.71)	2.010	0.052
	PNV > PPV	0.184 (0.65)	1.703	0.097
	TNV > PNV	0.526 (0.77)	4.100	**0.0002**
	TPV > PPV	0.474 (0.70)	4.085	**0.0002**
pSTG	TNC > TNV	0.116 (1.03)	0.679	0.501
	TPC > TPV	0.474 (0.86)	3.274	**0.002**
	PNC > PNV	0.221 (0.80)	1.663	0.105
	PPC > PPV	0.445 (0.79)	3.389	**0.002**
	TNV > TPV	0.526 (0.93)	3.392	**0.002**
	PNV > PPV	0.308 (0.86)	2.153	0.038
	TNV > PNV	0.310 (.081)	2.294	0.028
	TPV > PPV	.0092 (0.84)	0.661	0.513

The bold numbers indicate the significant values (Bonferroni-surviving). For abbreviations please see Data preprocessing section. Critical *p*-value = 0.006.

A three-way rmANOVA conducted on PSC in the left PO revealed a main Correctness effect ($F(1,35) = 7.43$, $p = 0.010$, $\eta_p^2 = 0.175$), indicating a larger PSC for the ungrammatical conditions as compared to the grammatical ones (2.76 vs. 2.61%SC). There was also a significant main effect of Language ($F(1,35) = 18.59$, $p = 0.00013$, $\eta_p^2 = 0.347$), indicating that the L1 conditions generated a larger PSC as compared to the L2 conditions (5.02 vs. 2.86%SC). A significant Correctness × Language interaction ($F_{(1,35)} = 7.87$, $p = 0.008$, $\eta_p^2 = 0.184$) was analyzed further (by Correctness). Mean PSC was significantly larger for the ungrammatical L1 conditions (3.009%SC) in comparison to the grammatical ones (2.710%SC) (t (35) = 3.49, p = 0.001) but for L2 there was no significant difference between ungrammatical (2.509% SC) and grammatical (2.508%SC) conditions (t (35) = 0.018, p = 0.985). The analysis by Language revealed no difference between the grammatical L1 conditions and L2 (2.710 vs. 2.508%SC) conditions (t (35) = 2.022, p = 0.051), but for the ungrammatical conditions a larger PSC emerged for L1 (3.009% SC) in comparison to L2 (2.509%SC) (t (35) = 5.285, p < 0.001). A significant interaction of Correctness × Feature ($F(1,35) = 5.59$, $p = 0.024$, $\eta_p^2 = 0.138$) was further analyzed, first by Correctness yielding a larger PSC for the ungrammatical than grammatical Number feature (2.864 vs. 2.575%SC) (t (35) = 3.570, p = 0.001); however, for Person feature, there was no differences between the ungrammatical and grammatical conditions (2.654 vs. 2.643%SC) (t (35) = 0.142, p = 0.888). Second, the analyses by feature showed that participants reacted similarly to ungrammatical sentences containing Number (2.864%SC) and Person feature (2.654%SC) (t (35) = 2.554, p = 0.015); similarly, there were no significant differences between grammatical sentences containing Number (2.575% SC) and Person feature (2.643%SC) (t (35) = -0.773, p = 0.445).

A three-way rmANOVA conducted on PSC in the pSTG revealed a main effect of Correctness ($F(1,35) = 11.91$, $p = 0.001$, $\eta_p^2 = 0.254$), indicating that on average grammatical conditions (4.711%SC) showed more PSC than ungrammatical conditions (4.397%SC). A Language effect ($F(1,35) = 7.44$, $p = 0.010$, $\eta_p^2 = 0.175$) revealed that overall L1 conditions (4.646%SC) elicited more PSC than L2 conditions (4.463%SC). Finally, a main effect of Feature ($F(1,35) = 11.27$, $p = 0.002$, $\eta_p^2 = 0.244$) showed that overall Number feature (4.690%SC) displayed a more PSC than Person feature (4.418%SC). A significant Correctness × Feature interaction ($F(1,35) = 6.32$, $p = 0.017$, $\eta_p^2 = 0.153$) showed, when analyzed by Correctness, more PSC for the grammatical as compared to ungrammatical Person feature (4.648 vs. 4.189%SC) (t (35) = 4.709, p < 0.001), but no differences between ungrammatical and grammatical Number feature (4.606 vs. 4.775%SC) (t (35) = -1.440, p = 0.159). In the post-hoc analysis by Feature, PSC to ungrammatical sentences containing Number feature was significantly larger than to ungrammatical sentences containing Person feature (4.606 vs. 4.189%SC) (t (35) = 3.970, p < 0.001), but no differences were found between Number and Person features in grammatical sentences (4.775 vs. 4.65%SC) (t (35) = 1.354, p = 0.185).

Discussion

The current reanalysis investigated whether the feature-checking and feature-mapping mechanisms involved in processing Number and Person agreement differ in their neural substrates. We were also interested to assess whether bilinguals differently process phi-features in L1 and L2. Considering two hypotheses (i.e., Agree vs. Spec-Head Relationship and the theory of phi-features), we analyzed phi-features processing of (relatively) early and highly proficient Turkish–Persian bilinguals, comparing L1 patterns to L2. Activation patterns in the frontotemporal network (the OP and the pSTG) indicated quantitative and qualitative differences between processing two features. As expected, higher RTs were found in L1 than L2 sentences. The results will be discussed in detail below.

At the whole-brain level, a sensitivity of the pSTG to Number Violations and Number and Person Correct conditions were observed for both L1 and L2. Also, this region was activated for L1 Person Violation conditions; however, the PO was selectively engaged for Number Violations in L1. This pattern is in accordance with the assumptions of the dorsal-ventral stream framework (Bornkessel-Schlesewsky & Schlesewsky, 2013) and neuroanatomical pathway hypothesis (Friederici et al., 2017) in which the dorsal stream (from BA 44 to the posterior STG) transfers information during form-to-meaning mapping at the sentence level. Specifically, the dorsal stream combines features in order to form successively more complex representations. Although the distribution of a given language function (i.e., phi-features) in the fronto-temporal network is still an open question, there are some predictions in this regard in the literature. The pSTG is suggested to provide a bridge to brain systems for action understanding (Bornkessel-Schlesewsky & Schlesewsky, 2013) and seems to be linked to competition for actorhood in the sense that the higher the degree of competition for the actor role within a sentence, the higher the activation observed within this region (Bornkessel-Schlesewsky & Schlesewsky, 2009). On the other hand, the PO has been established as a core region for syntactic processing during sentence comprehension (Friederici et al., 2017). Therefore the computation of the numerosity of an

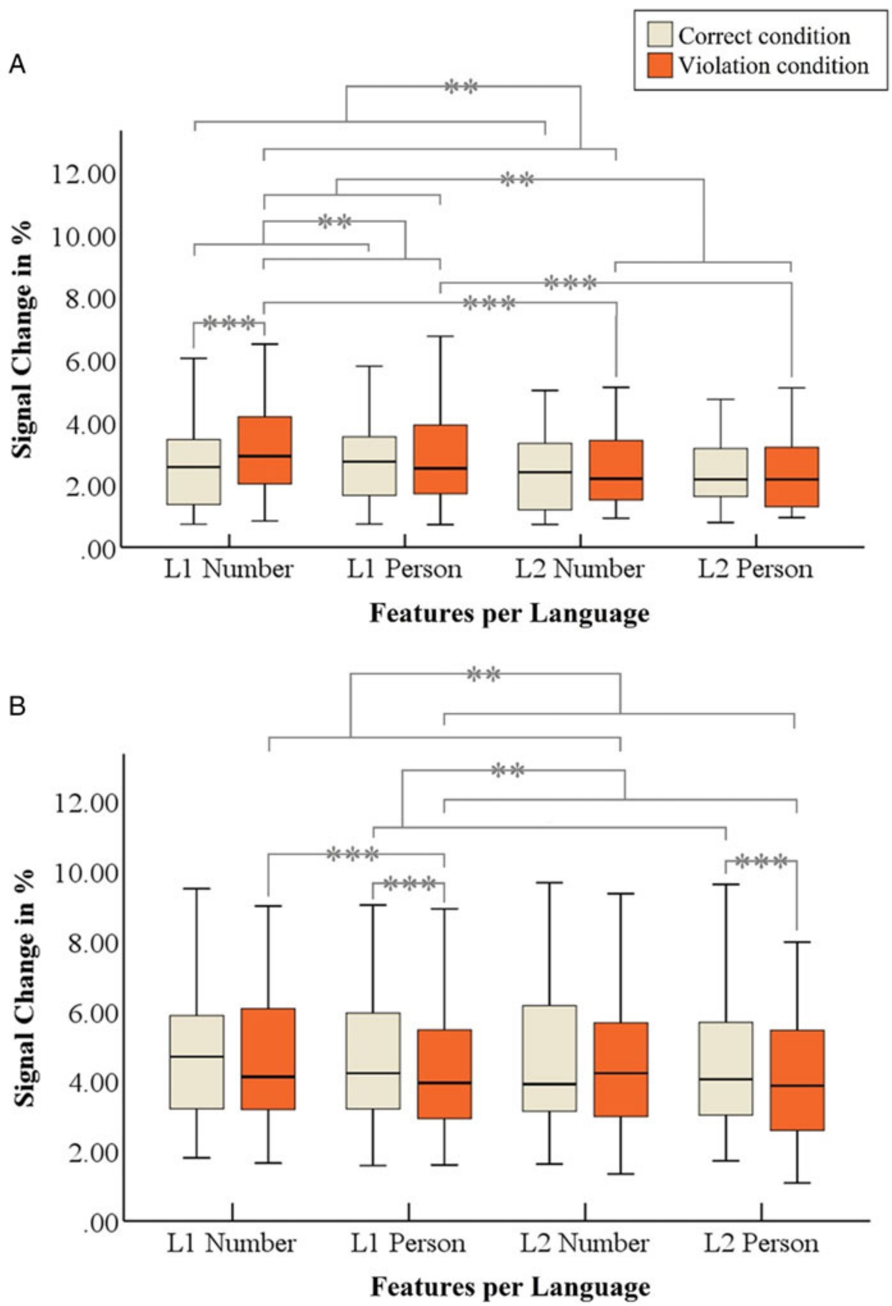

Figure 4. Box plots of percent signal change (PSC) for the Grammaticality effects, significant contrasts between Features/Languages and also significant interactions in (**A**) the pars opercularis and (**B**) and in the pSTG (***p = < 0.01, ***p = < 0.006*).

argument, which takes place during the syntactic build-up of a sentence (Mancini et al., 2013) may involve the PO. The involvement of Brodman's area 44, to which the PO belongs, in basic numerical computations such as simple arithmetic (i.e., $4 \times 7 = ?$) and numerical magnitude judgment (i.e., is 24 larger than 25?) was shown in an fMRI study by Rickard et al. (2000) and suggested to reflect not only calculation processing, but also the syntactic processing required to encode and comprehend the arithmetic problem. Overall, the present results corroborate the predictions of models regarding the involvement of the PO and the pSTG in manipulating cardinality and actor information, respectively.

Regarding phi-features processing in the PO and the pSTG regions, our findings indicate that the PO region is activated during the processing of Number feature, whereas the pSTG region is activated during the processing of Number and Person features, suggesting that Number features behave qualitatively differently from Person features. In the pSTG region which was sensitive to both features, on the other hand, a direct contrast between Number and Person Violations (as put forward by Mancini et al., 2017) has provided evidence in favour of stronger Number feature than Person feature processing, indicating the quantitative differences between Number and Person Violations. According to the hypotheses of phi-features theory (Ackema & Neeleman, 2013, 2018), which claims that R-expressions are specified for Number only, whereas pronouns are specified for both Number and Person features, we should not have observed the qualitative difference between Number and Person features that was found in the present reanalysis. On the other hand, because the repair of Person Violations is a two-step process (see

Ackema & Neeleman, 2019, for a more detailed discussion), there might be a quantitatively larger effect for Person Violation compared to Number Violation, which we did not observe. This is not, however, the whole story. The point is that the qualitative differences in the error detection and the quantitative distinctions in the repair phase seem to be originated from the specific subjects incorporated in the current study for both Violations – namely, R-expressions for Number Violations and Pronouns for Person Violations. Considering that our subjects were controlled for the parameters of "plurality/singularity", the effects observed for Number and Person features could be due to the different processing underlying R-expressions and pronouns. Although we share the conclusion that Number and Person Violations can lead to qualitative and quantitative differences with Mancini et al. (2017), the only existing fMRI work regarding phi-features processing, our findings differ in both error detection and repair phase, which may be due to different methodological constraints. More specifically, R-expressions and Pronouns acted as subjects in our study but only R-expressions were used by Mancini et al. (2017). Therefore, we propose that effects for Number Violations and Person Violations seem to be subject-dependent such that R-expressions trigger the stronger effects as compared to the pronouns. Although our study adds to previous literature on phi-features processing by showing that picking R-expressions or Pronouns as the subject may alter the strength of the Number and Person effects, future studies should replicate our design using R-expression and Pronoun as subject but only use Number violation instead in order to elucidate the nature of the subject.

Importantly, since our two regions of interest (i.e., the PO and the pSTG) were chosen based on the whole-brain analysis, a ROI analysis was subsequently performed to explore the pattern of activity across conditions per region (Poldrack, 2007). In the PO region, our results showed significant grammaticality effects for Number feature (i.e., Number Violations > Number Correct) only in L1, indicating that our previously reported grammaticality effects (Meykadeh et al., 2021a) for this region mainly stemmed from processing Number feature. In the pSTG region, we found significant grammaticality effects (i.e., Person Correct > Person Violations) for Person feature in both L1 and L2, although more prominent for L1. A reversed grammaticality effect (regardless of the features and languages manipulated) indicates that the decoding of grammatical consistency occurs in this region, which is known to be involved in lexical processing (Indefrey & Cutler, 2004; Hickok & Poeppel, 2004, 2007; Lau et al., 2006) and might be important for the retrieval of syntactic frames stored in the lexicon (Hagoort, 2013). It can also be inferred that pSTG involvement is not specific to the kind of violation used in the present study, but may rather reflect more general operations involved in the processing of ungrammatical sentences. As an example, an activation increase in Broca's area (pars opercularis/pars triangularis) was reported for grammatical errors as compared with spelling errors (Embick et al., 2000). The comparison of the reversed grammaticality effects in the pSTG with previous studies is limited in that no previous study has used the same manipulation; therefore, future research should address this issue more thoroughly. Correspondingly, Friederici et al. (2006) reported that the Broca's area was modulated by increasing linguistic complexity but not by the presence of a syntactic anomaly, suggesting that brain activation effects in the pars opercularis are indeed specific to the processing of linguistic hierarchies. Furthermore, the direct comparison between Person and Number Violations in the pSTG for L1 and L2 confirms the contribution of this region in processing Number feature only for L1, implying that this area, conceivably employed in the building and interpretation of sentential relations, operates in a feature-specific fashion in line with suggestions by Mancini et al. (2017).

The most obvious consequence of detecting two distinct neural substrates for two features is to conclude that they undergo separate feature-checking mechanisms, operating at different levels – namely, morphosyntactic and semantic-discourse. This proposition is in line with theoretically grounded claims that Number and Person phi-features occupy distinct positions in the syntactic tree. As an example, the maxim "one morphosyntactic property – one feature – one head" adopted in the Cartographic framework (Cinque & Rizzi, 2008) postulates that different functional projections are devoted to checking Number and Person. Analogously, another line of theoretical argument (Den Dikken, 2019) proposes different syntactic configurations for checking elements of agreement. In the case of Number agreement, both Agree and the Spec-Head checking would be at work, while only a Spec-Head configuration may be involved for Person agreement, since Agree-probe does not access the left periphery of sentence structure which constitute the interface with the situational context. With regards to mapping options (cardinality and discourse) which is behind the specific effects elicited by the two Violations (Mancini et al., 2017), we observed a larger effect for Number compared to Person Violations, supporting the previous claim (Mancini et al., 2017) about involving distinct feature-mapping mechanism during Number and Person processing, with Number mapping to cardinality and Person to the discourse. However, this is in contrast to the findings of Mancini et al. (2017) who reported a remarkable asymmetry between the two features in favor of Person Violations. Our finding may well be the consequence of our choice of pronominal subjects as the controller of Person Violations and R-expressions as the controller of Number Violations where both Violations contained a clash in feature specification (unlike the study of Mancini et al., 2017: in which there was no clash for Person Violation, since the R-expression is personless and leading to stronger response for Person as compared to Number feature). This pattern raised the possibility that the nature of subject (i.e., R-expressions or/and Pronouns) or even the position of a feature in the syntactic structure may cause greater brain activation as claimed by Mancini et al. (2017) and Ackema and Neeleman (2019). Although some caution is warranted, it can be said that the nature of agreement, handled by a dedicated operation of agree, which is a primitive operation of the syntactic component (Smith et al., 2020), may play a much more important and much more general role in this respect. Considering that Number information is hosted in the morphosyntactic layer of the sentence structure and Person is anchored to the speech act participant representation, it can be inferred that the computation of agreement relations takes place during the syntactic build-up of the sentence, independently of the thematic and semantic-pragmatic information of the arguments involved (Mancini et al., 2013). Hence, it is possible to argue that the linguistic system may presumably assign more weight to the morphosyntactic layer of the sentence structure than to the postsyntactic layer in form-to-meaning mapping. Taken together, these findings suggest that distinct feature-checking and feature-mapping mechanisms are at work for processing phi-features.

The final key result of the present study was the engagement of shared regions with notably distinguishable patterns for phi-features processing in L1 and L2, suggesting alternative interpretations. The first and most straightforward interpretation is that, in line with previous studies (Ullman, 2001; ; Perani & Abutalebi, 2005), L2 acquisition builds on the existing L1 system and, as L2 proficiency improves, syntactic processing becomes more native-like, substantiating the convergence hypothesis of Green (2003). The alternative interpretation is that the PO and the pSTG have feature-specific, not language-specific characteristics. The latter interpretation is partly consistent with a previous finding (Bornkessel-Schlesewsky & Schlesewsky, 2013) that describes the LIFG as a task-relevant but not language-specific region. However, we found a greater activation in L1 than L2 in all conditions. The most likely interpretation in this case is that during code-switching, both L1 and L2 are active but the base language is more strongly activated (Green, 1998). As suggested by Zhu et al. (2020), the higher activation of the base language (presumably L1) leads to asymmetrical switch effects. The strong suppression of L1 during L2 sentence processing has to be overcome when there is a switch back to L1 input, resulting in higher activation in the ROIs involved in suppression but also impaired performance of L1. This account of the fMRI results is also in line with the present performance results, with lower RTs and higher accuracy rate for L2 than L1 – that is, switching into the nondominant language (L2). In contrast, for switching into the dominant language (L1) it takes longer to overcome the prior inhibition applied on this language. In other words, because L2 is the weaker language, increased cognitive control is required to re-activate L2 after L1 production (Zhu et al., 2020). Hence, our participants may have relied more on their L1 than L2. Lack of an equivalent study in the context of bilingualism prompted us to discuss our results according to what was reported for native speakers (Mancini et al., 2017) and to a large extent in terms of the theoretical account proposed for phi-features agreement (Mancini et al., 2013; Ackema & Neeleman, 2018, 2019; Den Dikken, 2019). In a somewhat relevant study with bilinguals but ERPs, Martínez de la Hidalga et al. (2021) reported that bilingual speakers displayed a larger positivity for Person than for Number Violations in L2 processing, explaining the use of Pronouns as the subject in their all test sentences. When comparing their findings with a prior research (Martínez de la Hidalga et al., 2019) in which only the L1 materials have been presented, they proposed that bilingual speakers tended to generate larger negativity for person than for number in both L1 and L2. The point is that they presented their L1 and L2 materials to bilinguals in different sessions. In order to expand our investigation to native speakers, while avoiding the possible confounding from the syntactic differences between L1 and L2, we chose the similar languages of Turkish and Persian. The sensitivity of bilinguals to online feature-based processing confirmed the L2 learners' ability to simultaneously monitor syntactic and pragmatic information particularly in a language switching paradigm (as used here). Taken together, our results provide the first evidence that highly proficient bilinguals benefit from shared mechanisms in order to manage phi-features in L1 and L2.

Conclusion

To our knowledge, this study was the first to capture simultaneously L1 and L2 Number and Person phi-features processing in (relatively) early and highly proficient bilinguals. Specifically, our study provides novel neurophysiological information for the PO and the pSTG regions, which are equipped with feature-checking and feature-mapping mechanisms operating differently in identification of Number and Person features. Depending on which controller (i.e., R-expression or pronoun) for Number and Person feature are picked out by an experimental paradigm, the brain response may differ, highlighting the importance of subject type in detecting phi-features mechanisms. Secondly, our results supported our previous findings (Meykadeh et al., 2021a) that highly proficient bilinguals benefit from a shared mechanism in order to manage phi-features of L1 and L2.

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Notes

1 See also Merchant (2006), Baker (2008), Abels (2012) and Carstens (2016) for other hybrid proposals.
2 Den Dikken (2019) used the symbol # and the Greek letter π for the functional heads of Number and Person respectively. # and π, as two separate entities, involve in a complementation configuration with the #-head embedding πP as its complement. For a defense of this structure, see also Preminger (2011).
3 The following abbreviations are used in (1): CP = Complementizer Phrase; C = Complementizer; #P = Number Phrase; IND = INDIVIDUATION; πP = Person Phrase; PART = PARTICIPANT; VP = Verb Phrase and V = verb.
4 In Chomsky's binding theory, R-expression (short for "referring expression") is a category in the triple classification of noun phrases. Examples of typical R-expressions are individual names like "Mary" or "Lisa".
5 The full versions abbreviations are TNC = Turkish Number Correct; TPC = Turkish Person Correct; TNV = Turkish Number Violation; TPV = Turkish Person Violation; PNC = Persian Number Correct, PPC = Persian Person Correct; PNV = Persian Number Violation; and PPV = Persian Person Violation

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Appendix S1.

Stimuli used in the experiment (right column). Four types of sentences were constructed per language to produce four subject-verb Violation/Correct conditions (Number Violation; Person Violation; Number Correct and Person Correct). English translation is provided in the left column.

Number Violation (L1)		
The friend$_{3SG}$ sent$_{3PL}$ the books.	یولداش$_{3SG}$ کیتابلاری یولادیلار$_{3PL}$.	1
The brother$_{3SG}$ closed$_{3PL}$ his buttons.	قارداش$_{3SG}$ دوئملرین باغلادیلار$_{3PL}$.	2
The sister$_{3SG}$ liked$_{3PL}$ my book.	باجی$_{3SG}$ کیتابیمی سویوردولر$_{3PL}$.	3
The boy$_{3SG}$ frightened$_{3PL}$ his sisters.	اوغلان$_{3SG}$ باجیلارینی قورخوتدولار$_{3PL}$.	4
The child$_{3SG}$ found$_{3PL}$ his/her cloths.	اوشاخ$_{3SG}$ پالتارلارینی تاپدیلار$_{3PL}$.	5
The friend$_{3SG}$ did$_{3PL}$ his/her works.	یولداش$_{3SG}$ ایشلرینی گوردولر$_{3PL}$.	6
The friend$_{3SG}$ brought$_{3PL}$ his/her books.	یولداشیم$_{3SG}$ کیتابلاری گتیردیلر$_{3PL}$.	7
The brother$_{3SG}$ finished$_{3PL}$ his job.	قارداش$_{3SG}$ ایشینی کوتاردیلار$_{3PL}$.	8
The friends$_{3PL}$ sold$_{3SG}$ their houses.	یولداشلار$_{3PL}$ اولرینی ساتدی$_{3SG}$.	9
The boys$_{3PL}$ forgot$_{3SG}$ their wordings.	اوغلانلار$_{3PL}$ یازدیخلارینی اونوتدی$_{3SG}$.	10
Children$_{3PL}$ cut$_{3SG}$ the trees.	اوشاخلاریز$_{3PL}$ آغاچلاری سیندیردی$_{3SG}$.	11
The friends$_{3PL}$ tore$_{3SG}$ their cloths.	یولداشلار$_{3PL}$ پالتارلارین جیردی$_{3SG}$.	12
The mothers$_{3PL}$ dried$_{3SG}$ the cloths.	آنالار$_{3PL}$ پالتارلاری قوروتدی$_{3SG}$.	13
The mothers$_{3PL}$ asked$_{3SG}$ the questions.	آنالار$_{3PL}$ سوزلری سوروشدی$_{3SG}$.	14
The friends$_{3PL}$ drew$_{3SG}$ out plans.	یولداشلار$_{3PL}$ رسیملری چهدی$_{3SG}$.	15
Children$_{3PL}$ brought$_{3SG}$ their accordions.	اوشاخلار$_{3PL}$ گارمانلارینی گتیردی$_{3SG}$.	16
Person Violation (L1)		
I$_{1SG}$ realized$_{3SG}$ my friends.	من$_{1SG}$ یولداشیمی تانیدی$_{3SG}$.	17
I$_{1SG}$ chose$_{3SG}$ my cloths.	من$_{1SG}$ پالتارلاریمی سچدی$_{3SG}$.	18
I$_{1SG}$ saw$_{3SG}$ my parents.	من$_{1SG}$ آتاآنالاریمی گوردی$_{3SG}$.	19
I$_{1SG}$ called$_{3SG}$ my brothers.	من$_{1SG}$ قارداشلاریمی چاغئردی$_{3SG}$.	20
I$_{1SG}$ lost$_{3SG}$ my kids.	من$_{1SG}$ اوشاخلاریمی ایتیردی$_{3SG}$.	21

I$_{1SG}$ won$_{3SG}$ my games.	من$_{1SG}$ أیونلاریمی اوتدی$_{3SG}$.	22
I$_{1SG}$ wrote$_{3SG}$ their songs.	من$_{1SG}$ ماهنیلاریمیزی یازدی$_{3SG}$.	23
I$_{1SG}$ quitted$_{3SG}$ my jobs.	من$_{1SG}$ ایشلریمی اوتوردی$_{3SG}$.	24
We$_{1PL}$ read$_{3PL}$ our books.	بیز$_{1PL}$ کیتابلاریمیزی اوخودولار$_{3PL}$.	25
We$_{1PL}$ silenced$_{3PL}$ our babies.	بیز$_{1PL}$ اوشاخلاریمیزی اُاوندوردولار$_{3PL}$.	26
We$_{1PL}$ took$_{3PL}$ our new-year gift	بیز$_{1PL}$ بایراملیخلاریمیزی آلدولار$_{3PL}$.	27
We$_{1PL}$ sold$_{3PL}$ our homes.	بیز$_{1PL}$ اولریمیزی ساتدولار$_{3PL}$.	28
We$_{1PL}$ washed$_{3PL}$ our clothes.	بیز$_{1PL}$ پالتارلاریمیزی یودولار$_{3PL}$.	29
We$_{1PL}$ finished$_{3PL}$ our tasks.	بیز$_{1PL}$ ایشلریمیزی کوتاردولار$_{3PL}$.	30
We$_{1PL}$ cleaned$_{3PL}$ our homes.	بیز$_{1PL}$ اولریمیزی سیلدولر$_{3PL}$.	31
We$_{1PL}$ failed$_{3PL}$ in our matches.	بیز$_{1PL}$ أیونلاریمیزی اوتوزدولار$_{3PL}$.	32
Number Correct (L1)		
The brother$_{1SG}$ read$_{1SG}$ his book.	قارداش$_{1SG}$ کیتابلارینی اوخودی$_{1SG}$.	33
The nephew$_{1SG}$ cut$_{1SG}$ his finger.	قارداش‌اوغلو$_{1SG}$ بارماخلارینی کَسدی$_{1SG}$.	34
The niece$_{1SG}$ selected$_{1SG}$ her shoes.	باجی‌قیزیم$_{1SG}$ باشماخلارینی سچدی$_{1SG}$.	35
The brother$_{1SG}$ improved$_{1SG}$ his personality.	قارداش$_{1SG}$ دولانیشیغینی دیشدی$_{1SG}$.	36
Aras$_{1SG}$ broke$_{1SG}$ our glasses.	آراس$_{1SG}$ شوشه‌لریمیزی سیندیردی$_{1SG}$.	37
The niece$_{1SG}$ sold$_{1SG}$ her books.	باجی‌قیزیم$_{1SG}$ کیتابلارینی ساتدی$_{1SG}$.	38
The nephew$_{1SG}$ completed$_{1SG}$ her works.	قارداش‌اوغلو$_{1SG}$ ایشلرینی کوتاردی$_{1SG}$.	39
The niece$_{1SG}$ asked$_{1SG}$ her questions.	باجی‌قیزیم$_{1SG}$ سوزلرینی سوروشدی$_{1SG}$.	40
The sisters$_{3PL}$ returned$_{3PL}$ from the travel.	باجیلار$_{3PL}$ دولانماخدان قئیدیلر$_{3PL}$.	41
The farmers$_{3PL}$ harvested$_{3PL}$ the wheat.	اکینچیلر$_{3PL}$ بوغدالاری بیچدیلر$_{3PL}$.	42
Children$_{3PL}$ played$_{3PL}$ with dolls.	اوشاخلار$_{3PL}$ قولچاخینان اوینادیلار$_{3PL}$.	43
The sellers$_{3PL}$ sold$_{3PL}$ the shoes.	توکانچیلار$_{3PL}$ باشماخلاری ساتدیلار$_{3PL}$.	44
The boys$_{3PL}$ burned$_{3PL}$ the firewood.	اوغلانار$_{3PL}$ اودونلاری یاندیردیلار$_{3PL}$.	45
The brothers$_{3PL}$ washed$_{3PL}$ their clothes.	قارداشلار$_{3PL}$ پالتارلارین یودولار$_{3PL}$.	46
The guests$_{3PL}$ ate$_{3PL}$ the watermelons.	قوناخلار$_{3PL}$ قارپیزلاری یدیلر$_{3PL}$.	47
The workers$_{3PL}$ cleansed$_{3PL}$ our houses.	ایشچیلر$_{3PL}$ اویمیزی سوپوردولر$_{3PL}$.	48
Person Correct (L1)		
I$_{1SG}$ upset$_{1SG}$ my sister.	من$_{1SG}$ باجیمی جینلتدیم$_{1SG}$.	49
I$_{1SG}$ said$_{1SG}$ my words.	من$_{1SG}$ سوزلریمی دِدیم$_{1SG}$.	50
I$_{1SG}$ inquired$_{1SG}$ my ambiguities.	من$_{1SG}$ بیلمدوخلاریمی سوروشدیم$_{1SG}$.	51
I$_{1SG}$ asked$_{1SG}$ my questions.	من$_{1SG}$ سوزلریمی سوروشدیم$_{1SG}$.	52
I$_{1SG}$ accompanied$_{1SG}$ my guests.	من$_{1SG}$ گوناخلاریمی یولاسالدیم$_{1SG}$.	53
I$_{1SG}$ hugged$_{1SG}$ my children.	من$_{1SG}$ اوشاخلاریمی گوجاخلادیم$_{1SG}$.	54
I$_{1SG}$ cut$_{1SG}$ my fingers.	من$_{1SG}$ بارماخلاریمی کَسدیم$_{1SG}$.	55
I$_{1SG}$ put$_{1SG}$ on my cloths.	من$_{1SG}$ پالتارلاریمی یودوم$_{1SG}$.	56
We$_{1PL}$ changed$_{1PL}$ our views.	بیز$_{1PL}$ دوشونجلریمیزی دئیشدیخ$_{1PL}$.	57
We$_{1PL}$ calmed$_{1PL}$ down our kids.	بیز$_{1PL}$ اوشاخلاریمیزی اُاوندوردوخ$_{1PL}$.	58
We$_{1PL}$ faced$_{1PL}$ many hardships.	بیز$_{1PL}$ چتینلیخلاری سوئوشدوردوخ$_{1PL}$.	59
We$_{1PL}$ convoyed$_{1PL}$ the visitors.	بیز$_{1PL}$ گوناخلاریمیزی یولاسالدوخ$_{1PL}$.	60
We$_{1PL}$ embraced$_{1PL}$ our children.	بیز$_{1PL}$ اوشاخلاریمیزی گوجاخلادیخ$_{1PL}$.	61
We$_{1PL}$ reconciled$_{1PL}$ our neighbors.	بیز$_{1PL}$ قُنشولاریمیزی باریشدیردوخ$_{1PL}$.	62
We$_{1PL}$ gladdened$_{1PL}$ our parents.	بیز$_{1PL}$ آتاآنامیزی سوئوندوردوخ$_{1PL}$.	63
We$_{1PL}$ promenaded$_{1PL}$ with our friends.	بیز$_{1PL}$ یولداشلاریمیزینان دولاندوخ$_{1PL}$.	64
Number Violation (L2)		
The accountant$_{3SG}$ paid$_{3PL}$ the payment.	حسابدار$_{3SG}$ حقوق را پرداختند$_{3PL}$.	65
The professor$_{3SG}$ frightened$_{3PL}$ the students.	استاد$_{3SG}$ دانشجو را ترساندند$_{3PL}$.	66
The businessman$_{3SG}$ sold$_{3PL}$ the property.	بنگهدار$_{3SG}$ املاک را فروختند$_{3PL}$.	67
The engineer$_{3SG}$ built$_{3PL}$ the railroad.	مهندس$_{3SG}$ راه‌آهن را ساختند$_{3PL}$.	68
The student$_{3SG}$ wrote$_{3PL}$ the thesis.	دانشجو$_{3SG}$ رساله را نوشتند$_{3PL}$.	69
The climber$_{3SG}$ brought$_{3PL}$ the equipment.	کوهنورد$_{3SG}$ وسایل را آوردند$_{3PL}$.	70
The passenger$_{3SG}$ packed$_{3PL}$ the luggage.	مسافر$_{3SG}$ چمدان را بستند$_{3PL}$.	71
The musician$_{3SG}$ played$_{3PL}$ the song.	نوازنده$_{3SG}$ آهنگ را نواختند$_{3PL}$.	72
The farmers$_{3PL}$ planted$_{3SG}$ their crops.	کشاورزان$_{3PL}$ محصولاتشان را کاشت$_{3SG}$.	73
The spectators$_{3PL}$ saw$_{3SG}$ the players.	تماشاگران$_{3PL}$ بازیکنان را دید$_{3SG}$.	74
The police$_{3PL}$ brought$_{3SG}$ our belongings.	پلیس‌ها$_{3PL}$ وسایلمان را آورد$_{3SG}$.	75
The soldiers$_{3PL}$ fought$_{3SG}$ with enemies.	سربازان$_{3PL}$ با دشمنان جنگید$_{3SG}$.	76

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The pupils$_{3PL}$ bought$_{3SG}$ their gifts.	دانش‌آموزان$_{3PL}$ هدایایشان را خرید$_{3SG}$.	77
The tourists$_{3PL}$ bought$_{3SG}$ their souvenirs.	گردشگران$_{3PL}$ سوغاتی‌شان را خرید$_{3SG}$.	78
The translators$_{3PL}$ took$_{3SG}$ their books.	مترجمین$_{3PL}$ کتابهایشان را برد$_{3SG}$.	79
The researchers$_{3PL}$ delivered$_{3SG}$ their documents.	پژوهشگران$_{3PL}$ مدارکشان را گرفت$_{3SG}$.	80
Person Violation (L2)		
I$_{1SG}$ read$_{3SG}$ their dissertations.	من$_{1SG}$ پایان‌نامه‌هایشان را خواند$_{3SG}$.	81
I$_{1SG}$ wrote$_{3SG}$ the instructions.	من$_{1SG}$ دستورالعمل‌ها را نوشت$_{3SG}$.	82
I$_{1SG}$ carried$_{3SG}$ their books.	من$_{1SG}$ کتابهایشان را برد$_{3SG}$.	83
I$_{1SG}$ paid$_{3SG}$ their expenses.	من$_{1SG}$ هزینه‌هایشان را پرداخت$_{3SG}$.	84
I$_{1SG}$ took$_{3SG}$ our stipend.	من$_{1SG}$ حق‌الزحمه‌مان را گرفت$_{3SG}$.	85
I$_{1SG}$ sent$_{3SG}$ their letters.	من$_{1SG}$ نامه‌هایشان را فرستاد$_{3SG}$.	86
I$_{1SG}$ sew$_{3SG}$ their cloths.	من$_{1SG}$ لباس‌هایشان را دوخت$_{3SG}$.	87
I$_{1SG}$ sent$_{3SG}$ their parcels.	من$_{1SG}$ بسته‌هایتان را فرستاد$_{3SG}$.	88
We$_{1PL}$ passed$_{3PL}$ our difficulties.	ما$_{1PL}$ مشکلاتمان را گذراندند$_{3PL}$.	89
We$_{1PL}$ heard$_{3PL}$ our songs.	ما$_{1PL}$ ترانه‌هایان را شنیدند$_{3PL}$.	90
We$_{1PL}$ ate$_{3PL}$ our food.	ما$_{1PL}$ غذایمان را خوردند$_{3PL}$.	91
We$_{1PL}$ threatened$_{3PL}$ our brothers.	ما$_{1PL}$ برادرانمان را ترساندند$_{3PL}$.	92
We$_{1PL}$ liked$_{3PL}$ our behaviour.	ما$_{1PL}$ رفتارمان را پسندیدند$_{3PL}$.	93
We$_{1PL}$ draw$_{3PL}$ their paints.	ما$_{1PL}$ نقاشی هایشان را کشیدند$_{3PL}$.	94
We$_{1PL}$ read$_{3PL}$ their papers.	ما$_{1PL}$ مقالاتشان را خواندند$_{3PL}$.	95
We$_{1PL}$ accepted$_{3PL}$ their situation.	ما$_{1PL}$ شرایطشان را پذیرفتند$_{3PL}$.	96
Number Correct (L2)		
The nurse$_{3SG}$ accepted$_{3SG}$ his/her patients.	پرستار$_{3SG}$ بیمارانش را پذیرفت$_{3SG}$.	97
The student$_{3SG}$ wrote$_{3SG}$ her homework.	دانش‌آموز$_{3SG}$ تکالیفش را نوشت$_{3SG}$.	98
The agent$_{3SG}$ asked$_{3SG}$ his/her questions.	نماینده$_{3SG}$ سوالاتش را پرسید$_{3SG}$.	99
The lawyer$_{3SG}$ read$_{3SG}$ the case.	وکیل$_{3SG}$ پرونده را خواند$_{3SG}$.	100
The manager$_{3SG}$ knew$_{3SG}$ his/her staffs.	مدیر$_{3SG}$ کارکنانش را شناخت$_{3SG}$.	101
The university$_{3SG}$ accepted$_{3SG}$ my document.	دانشگاه$_{3SG}$ مدارکم را پذیرفت$_{3SG}$.	102
The writer$_{3SG}$ sold$_{3SG}$ his/her books.	نویسنده$_{3SG}$ کتابهایش را فروخت$_{3SG}$.	103
The astronaut$_{3SG}$ achieved$_{3SG}$ his/her dreams.	فضانورد$_{3SG}$ به آرزوهایش رسید$_{3SG}$.	104
The pupils$_{3PL}$ saw$_{3PL}$ their teachers.	شاگردان$_{3PL}$ معلم‌شان را دیدند$_{3PL}$.	105
The workers$_{3PL}$ got$_{3PL}$ their salaries.	کارگران$_{3PL}$ حقوقشان را گرفتند$_{3PL}$.	106
The gardeners$_{3PL}$ cut$_{3PL}$ the trees.	باغبانان$_{3PL}$ درختان را بریدند$_{3PL}$.	107
The citizens$_{3PL}$ built$_{3PL}$ their homes.	شهروندان$_{3PL}$ منازلشان را ساختند$_{3PL}$.	108
The artists$_{3PL}$ said$_{3PL}$ their secrets.	هنرمندان$_{3PL}$ اسرارشان را گفتند$_{3PL}$.	109
The students$_{3PL}$ taught$_{3PL}$ the lesson.	دانش آموزان$_{3PL}$ درس را آموختند$_{3PL}$.	110
The students$_{3PL}$ understood$_{3PL}$ the contents.	دانشجویان$_{3PL}$ مطالب را فهمیدند$_{3PL}$.	111
The athletes$_{3PL}$ lost$_{3PL}$ the race.	ورزشکاران$_{3PL}$ مسابقه را باختند$_{3PL}$.	112
Person Correct (L2)		
I$_{1SG}$ heard$_{1SG}$ their suggestions.	من$_{1SG}$ پیشنهاداتشان را شنیدم$_{1SG}$.	113
I$_{1SG}$ accepted$_{1SG}$ their critics.	من$_{1SG}$ انتقاداتش را پذیرفتم$_{1SG}$.	114
I$_{1SG}$ paid$_{1SG}$ our debts.	من$_{1SG}$ بدهکاریمان را پرداختم$_{1SG}$.	115
I$_{1SG}$ heard$_{1SG}$ her/his talks.	من$_{1SG}$ سخنرانی‌هایش را شنیدم$_{1SG}$.	116
I$_{1SG}$ saw$_{1SG}$ her/his successes.	من$_{1SG}$ موفقیت‌هایش را دیدم$_{1SG}$.	117
I$_{1SG}$ accepted$_{1SG}$ their views.	من$_{1SG}$ نظراتشان را پذیرفتم$_{1SG}$.	118
I$_{1SG}$ heard$_{1SG}$ their advices.	من$_{1SG}$ نصیحت‌هایشان را شنیدم$_{1SG}$.	119
I$_{1SG}$ accepted$_{1SG}$ their situations.	من$_{1SG}$ شرایطشان را پذیرفتم$_{1SG}$.	120
We$_{1PL}$ wrote$_{1PL}$ the guidelines.	ما$_{1PL}$ دستورالعمل‌ها را نوشتیم$_{1PL}$.	121
We$_{1PL}$ paid$_{1PL}$ our debts.	ما$_{1PL}$ بدهکاریمان را پرداختیم$_{1PL}$.	122
We$_{1PL}$ got$_{1PL}$ our salaries.	ما$_{1PL}$ حق‌الزحمهیمان را گرفتیم$_{1PL}$.	123
We$_{1PL}$ draw$_{1PL}$ our paints.	ما$_{1PL}$ نقاشی‌هایمان را کشیدیم$_{1PL}$.	124
We$_{1PL}$ knew$_{1PL}$ our neighbors.	ما$_{1PL}$ همسایگانمان را شناختیم$_{1PL}$.	125
We$_{1PL}$ saw$_{1PL}$ their sacrifices.	ما$_{1PL}$ فداکاری‌هایشان را دیدیم$_{1PL}$.	126
We$_{1PL}$ heard$_{1PL}$ their talks.	ما$_{1PL}$ سخنرانی‌هایش را شنیدیم$_{1PL}$.	127
We$_{1PL}$ sent$_{1PL}$ their books.	ما$_{1PL}$ کتابهایشان را فرستادیم$_{1PL}$.	128

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