Slavic languages in the Black Box, 2014

Debates on Mental Lexicon and its Cerebral Basis: Evidence from Russian

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Outline

(1)... half a billion years ago

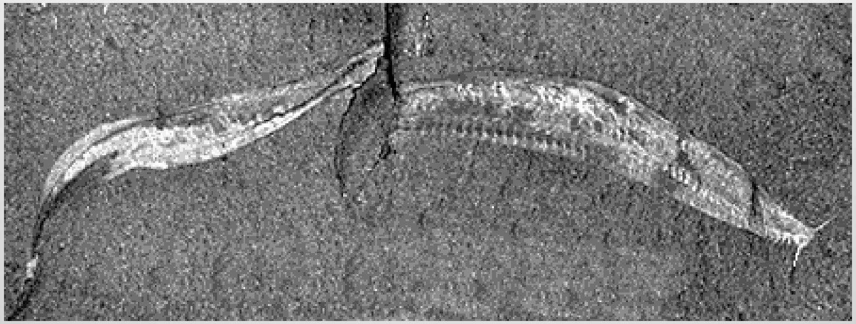
(2) From animal communication to Human language – genes and specifics

(3) Cerebral asymmetry and language

(4) Neural networks vs. modularity in mental lexicon structure

(5) Russian verb morphology production and functional connectivity (neuroimaging)

Pikaia gracilens (a primitive chordate)



- Averaging about one and a half inches in length, *Pikaia* swam above the seafloor. *Pikaia* is not a vertebrate. Nevertheless, *Pikaia* is a member of the *chordate* group from which we undoubtedly arose. It resembles a living chordate commonly known as the lancelet.

- If a *Pikaia gracilens* had not survived the Cambrian extinction the entire phylum Chordata, which includes us vertebrates, might never have existed. The fact that any of our ancestral species might easily not survive should fill us with amazement.

D. Premack:

Human language
is an embarrassment
for evolutionary theory

Who are we? One of many but more complex?

Talking great-grand-children of primates?

Symbolic minds? Semiotic animals?

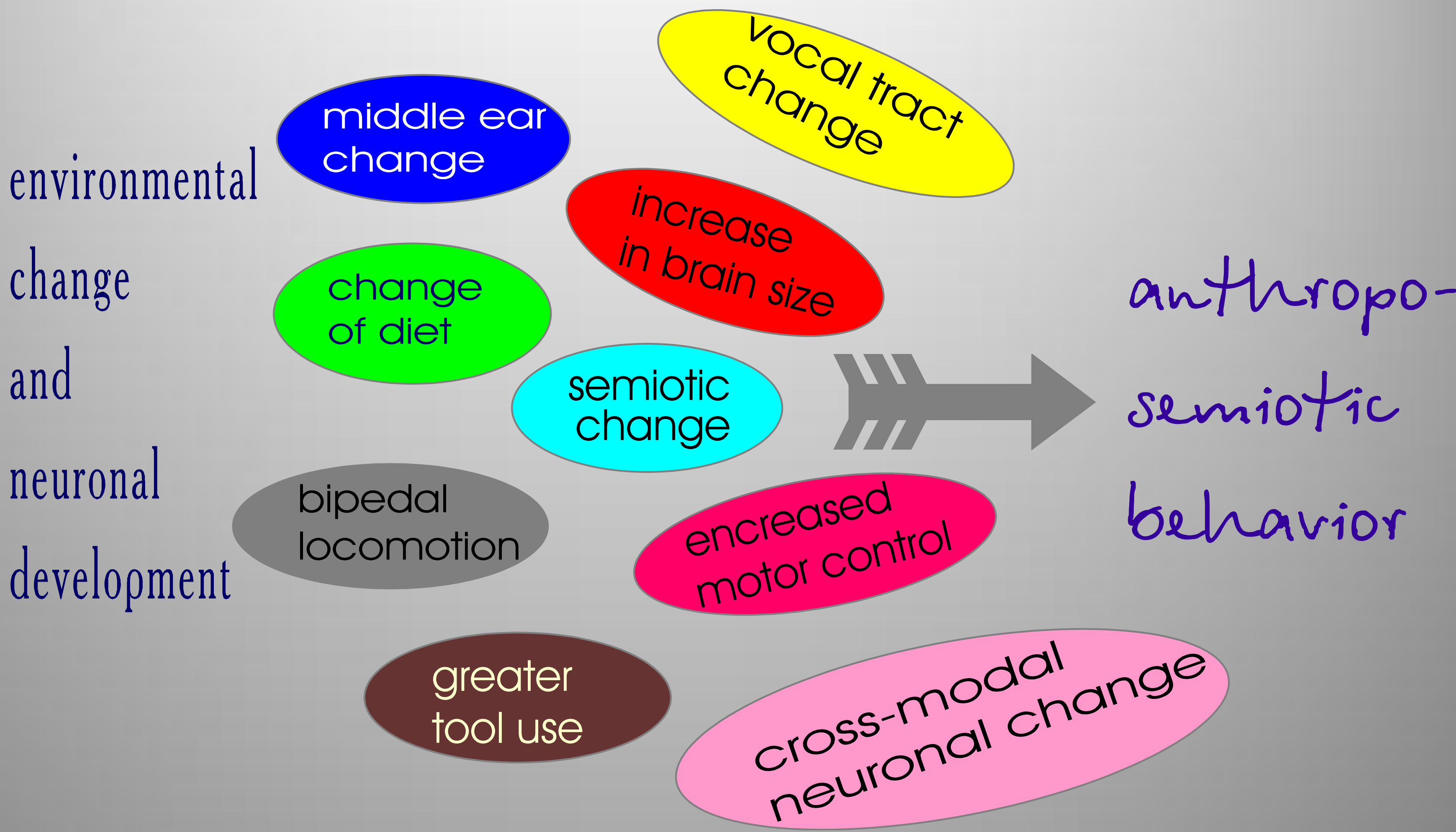
Any human specific genes?

Why study language-mind-brain puzzle?

Our words are bound by an invisible grammar which is embedded in the brain

- All the languages have some mutual specific universal features: e.g. phonology, recursion in syntax.
- The features are probably innate.
- Changing meaning following the background of the writer/speaker and the reader/listener. Context dependence!
- On-line processing! All the time! No stable fixed meaning of items – just clouds=semantic clusters of some prototypes or concepts (some - most general – inborn J. Fodor's), and even their borders are not stable and subjective.

channeling evolution in the hominid direction



Hunting for The Human Gene… A gene for Language?

FoxP2, FoxB1. HARF1…..

- What we know is that a specific gene-group has been found - HAR - that caused evolutionary acceleration of the frontal regions of the cortex in our ancestors and it developed 70! times as quick as the other parts of the brain. So, what did it give us? Quick computation!

The Neandertal and Denisova genomes allow novel genomic features that appeared and became fixed in present-day humans since their divergence from common ancestors with these archaic humans to be identified, and regions likely to have been affected by positive selection in modern humans s to be identified. Analysis shows the evolution FOXP2 in humans, a gene involved in the development of speech and language
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U. BORNSCHEIN, W. ENARD, S. PÄÄBO, W. HEVERS. Characterization of striatal long-term plasticity in mice expressing a humanized version of FOXP2

C. SCHREIWEIS et al. Humanized Foxp2 alters learning in differently balanced cortico-basal ganglia circuits

SCIENCE:22 NOVEMBER 2013 Vol. 342

- Philip Lieberman. Synapses, Language, and Being Human.
- We do not yet know the full range of genetic events that yielded the human brain, but an amino acid mutations at a site near the FOXP2 that are unique to humans appear to be responsible for a ‘selective sweep’ that occurred about 200,000 years ago in Africa. Such sweeps on genes occur when they enhance the survival of progeny. A process in which FOXP2 targets the SRPX2 gene to control the release of a protein that promotes the development of synapses that would clearly play a role in that aspect of the evolution of the human brain.

Humanized Foxp2 alters learning in differently balanced cortico-basal ganglia circuits

C. SCHREIWEIS et al.

When human version of Foxp2 is introduced into the endogenous gene of mice, they specifically affect cortico-basal ganglia circuits on a molecular, neuroanatomical and electrophysiological level. Humanizing Foxp2 enhances the efficiency of stimulus-response learning due to a stronger tendency for procedural versus declarative strategies. The findings suggest that human FOXP2 might have altered the balance of cortico-basal ganglia circuits and learning depending on those circuits. Such a shift could be important for the evolution of vocal learning in general and for language and speech in particular.

Currently, one can only speculate about the role these effects may have played during human evolution. However, since patients that carry one nonfunctional FOXP2 allele show impairments in the timing and sequencing of orofacial movements (Alcock et al., 2000; Watkins et al., 2002a), one possibility is that the amino acid substitutions in FOXP2 contributed to an increased fine-tuning of motor control necessary for articulation, i.e., the unique human capacity to learn and coordinate the muscle movements in lungs, larynx, tongue and lips that are necessary for speech (Lieberman, 2006)

FOXP2 is a 'hub' in a network of genes which might be important for developing language

A Humanized Version of Foxp2 Affects Cortico-Basal Ganglia Circuits in Mice **Wolfgang et al**. // Cell 137, 961–971, May 29, 2009 Elsevier Inc.

SCIENCE:22 NOVEMBER 2013 Vol. 342

- G. M. Sia, R. L. Clem, R. L. Huganir. The Human Language–Associated Gene SRPX2 Regulates Synapse Formation and Vocalization in Mice
- Expression of this protein is known to be repressed by the transcription factor FOXP2, which has been implicated in human language acquisition.

Broca's Area as an organ of action orchestration

- Areas 44/45 comprise a sequence orchestration part of the brain. This includes speech movements and also manual movements with the complexity (such as gestures).

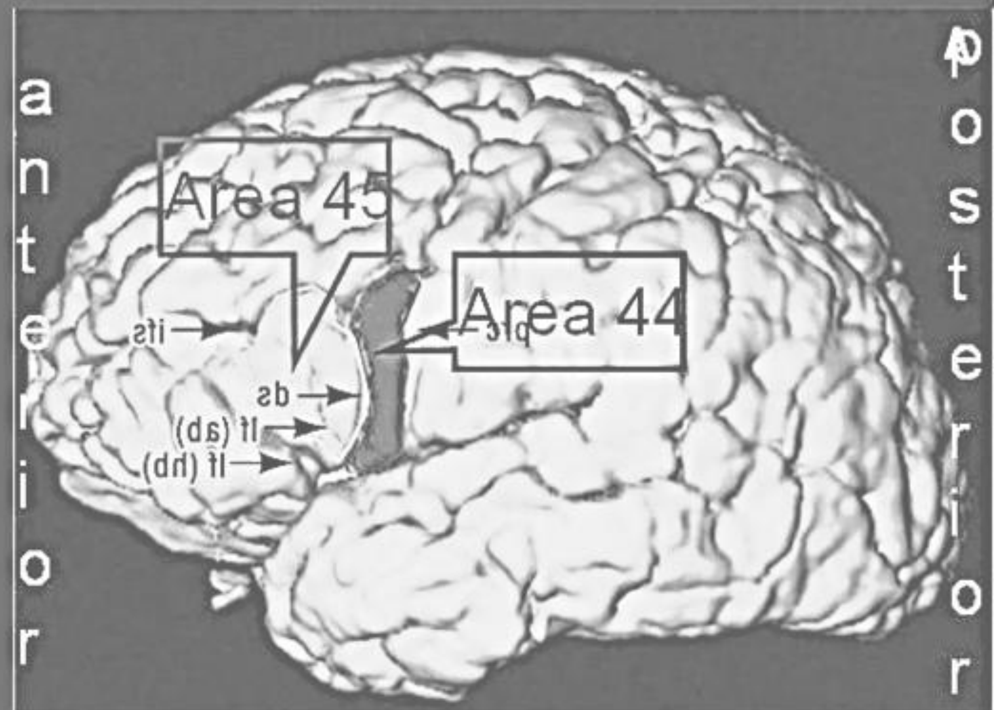


Image flipped to appear as left hemisphere

Left brain subserves specific features of human language

- ‘Digital’ and hierarchical structure (phonemes - morphemes - words -phrases - discourse)
- Productivity governed by the linguistic rules
- Differences in the superficial order of constituents

Left brain subserves specific features of human language

- The use of null elements (e.g. ‘it’, ‘there’)
- The use of sub-categorical argument structure for verbs
- Mechanisms for expansion of utterances
- Embedding

The Right Brain is responsible for

- Global/Gestalt recognition.
- Revealing the relevant components of a situation (or a scene).
- Relatively high speed of decision making
- Classification of colours and odours
- Orientation in space and time
- Evaluation of gestures, face expressions and verbal prosody

- Cerebral asymmetry is claimed to be the important factor of human evolution and the basis for human linguistic competence.
- However, we see not only a cross-hemispheric dialogue, but hundreds of ‘cross-talks’ all over the brain subserving all cognitive procedures

- Poeppel D (2003) The analysis of speech in different temporal integration windows: Cerebral lateralization as ‘asymmetric sampling in time’. Speech Communication 41(1):245–255.
- Fox MD, et al. (2005) The human brain is intrinsically organized into dynamic, anti-correlated functional networks. Proc Natl Acad Sci USA 102(27):9673–9678.
- Hickok G, Poeppel D (2007) The cortical organization of speech processing. Nat Rev. Neurosci 8(5):393–402
- Rosch RE, Bishop DV, Badcock NA (2012) Lateralised visual attention is unrelated to language lateralisation, and not influenced by task difficulty - a functional transcranial Doppler study. Neuropsychologia 50(5):810–815.

What we know now: Modularity vs. Connectionism

The cortex is a network – no modules or blocks

- So, the cortical representation of language is a network
- The cortical representation of knowledge in general is a network
- The representation of memory is a network
- Language uses the same cortical structures and processes as other cognitive skills
  - Except for phonetics, which has specialization (FOXP2?)

- The regions in the right hemisphere, homologous to Broca's and Wernicke's areas, were also implicated during syntactic processing (Just et al., 1996). Humphries et al. (2001) found bilateral activations in the anterior temporal cortex during speech sounds, as opposed to non-speech sounds. In their PET study, Mazoyer et al. (1993) showed that the **bilateral** anterior temporal cortex was the only structure specifically activated by listening to sentences, whereas Broca's area was activated also by separate words. Friedericci et al. (2000) also showed that syntactic processing of speech **bilaterally influenced** anterior temporal cortex activation. Thus, syntactic processing seems to be subserved by the **cross-hemispheric neural networks.**

- The right posterior prefrontal cortex and the right medial posterior cerebellar area participate in the brain network of spoken speech syntactic parsing, being involved in the prosody/syntax interface. The acquired ERP data support the idea that prosody-based semantic prediction is important for such processing. Furthermore, comparing our results with other brain mapping studies, we conclude that the right posterior prefrontal cortex might represent the functional overlap of brain networks of emotions, prosody, and syntax perception.

AD Friedericci. The Brain Basis of Language Processing: From Structure to Function.*Physiol Rev 2011* 91: 1357–1392

Networks involving the temporal cortex and the inferior frontal cortex with a clear left lateralization were shown to support syntactic processes, whereas less lateralized temporo-frontal networks subserve semantic processes. Suprasegmental prosodic information overtly available in the acoustic language input is processed predominantly in a temporo-frontal network in the right hemisphere. Studies with patients suffering from lesions in the corpus callosum reveal that the posterior portion of this structure plays a crucial role in the interaction of syntactic and prosodic information during language processing.

R. L. Moseley, F. Pulvermu¨ller & Yu. Shtyrov.
SCIENTIFIC REPORTS -June, 2013

Although semantic processing has traditionally been associated with brain responses maximal at 350–400 ms, recent studies reported that words of different semantic types elicit topographically distinct brain responses substantially earlier, at 100–200 ms. Action-related words most strongly activated frontocentral motor areas and visual object-words occipitotemporal cortex. These data now show that different cortical areas are activated rapidly by words with different meanings and that aspects of their category-specific semantics is reflected by dissociating neurophysiological sources in motor and visual brain systems.

- At the same time, functional imaging of the brain provides an increasing amount of quite controversial data (Shapiro, Caramazza 2003, Démonet, Thierry, Cardebat, 2005) that are rather difficult for combining not only with such paradigms, but even with results from other fields of the presumably common scientific object: right are aphasiologists describing agrammatism in disturbances of the Broca zone, while the facts of agrammatism in Wernike patients do not agree with any general concepts

Thus the function of a brain area should be considered within a neural network of which it is a part.

Changes in functional connectivity induced by regular and irregular Russian verb production

- Inflectional morphology is at the center of an important debate in cognitive science, concerning the general principles according to which the mental lexicon is organized. So-called Dual-system (DS) approach distinguishes regular and irregular morphological forms. The former are computed by rules, the latter are stored in the memory. In the alternative Single-system (SS) approach, all forms are generated and processed by a single integrated system.

- Initially, English past tense morphology was the testing ground for both approaches. According to the ‘Words and Rules’ model, a version of DS approach proposed by Pinker (1991, 1999), regular past tense forms are generated and processed by a symbolic rule that is part of the productive, combinatorial system of grammar. Irregular forms are learned by rote and stored in the lexicon, from where they can be retrieved through associative memory mechanisms. The DS approach was also advocated e.g. in (Marslen-Wilson & Tyler, 1997; Pinker & Prince, 1988; Ullman, 2004).

- On the contrary, a connectionist network model from (Rumelhart & McClelland, 1986) represents a single system without any symbolic rules. All past tense forms are generated and processed by associative mechanisms that take into account phonological similarity and token and type frequencies of different elements. The SS approach was further developed e.g. in (MacWhinney & Leinbach, 1991; Plunkett & Marchman, 1993; McClelland & Patterson, 2002;).

- The range of data used to test SS and DS theories has been very diverse: behavioral and neurophysiological experiments where participants generated forms from various real and nonce verbs, language acquisition and language deficit studies, and computer simulations.
- The results have always been controversial.

- However, English past tense morphology is exceptionally simple: there is only one productive class that includes the vast majority of verbs and a small number of irregular verbs. So various authors investigated verb and noun inflection in other languages where the situation is more complex. German, Icelandic, Norwegian, Italian, Spanish, Russian, Arabic and Hebrew are among them (e.g. Berent et al., 1999; Clahsen, 1999; Clahsen et al., 2002; Hahn & Nakisa, 2000; Orsolini & Marslen-Wilson, 1997, Orsolini et al., 1998; Plunkett & Nakisa, 1997; Ragnasdóttir et al., 1999; and our group)

- Thus, widening the pool of languages was extremely important for the SS vs. DS debate.
- English, German and, in one case, Spanish imaging data (Beretta et al., 2003; de Diego-Balaguer et al., 2006; Desai et al., 2006; Dhond et al., 2003; Indefrey et al., 1997; Jaeger et al., 1996; Joanisse & Seidenberg, 2005; Oh et al., 2011; Sach et al., 2004; Sahin et al., 2006; Ullman et al., 1997a). There are also electrophysiological studies dedicated to past tense formation in English and German (e.g. Lavric et al., 2001; Marslen-Wilson & Tyler, 1998; Münte et al., 1999; Newman et al., 1999, 2007), which show variable results.

Predictions from DS

Dual system approach:

Fronto-temporal neuronal network is responsible for regular form production. Left lateralized combinatorial network.

Irregular form production associated with memory-based processes and involvement of temporal-parietal regions. Bilateral system.

Russian verb morphology

Several approaches… Jacobson (1948) and his followers: 11 classes, out of them 5 productive, all differ in type frequency. 10 classes are identified by their suffixes, 11^{th} class consists of 13 subclasses with lowest type frequency and various conjugation patterns.

Let us first look at the two poles of this system:

- AJ class: productive, the most frequent
- 11^{th} class: non-productive, the least frequent

- All verbs have two stems: the present/future tense stem and the past tense stem. Depending on the class, the correlation between them may include truncations or additions of the final consonant or vowel, stress shifts, suffix alternations, alternations of stem vowels and stem-final consonants. The verb class also determines which set of endings is used in the present and future tense (1st and 2nd conjugation types).

- Usually, the class is unrecoverable from a particular form:e.g. *délat*’ ‘to do’ belongs to the AJ class, and its 3Pl pres.tense form is *déla*-*j*-*ut* (-j- suffix is added, 1st conjugation type). *Pisát’* ‘to write’ belongs to the A class, and its 3Pl present tense form is *píš*-*ut* (-a- suffix is truncated, 1st conjugation type, final consonant alternation, stress shift). *Deržát’* ‘to hold’ belongs to the ZHA class, and its 3Pl pres.tense form is *dérž-at* (-a- suffix is truncated, 2nd conj. type)

- Verb classes dramatically differ in frequency, and five of them are productive. Thus, there is no single productive pattern that can be applied to any stem, and no obvious division into regular and irregular verbs in this system. In our fMRI experiment, we looked at the two poles of this system, comparing verbs from the most frequent and productive AJ class to verbs from small unproductive classes. For the sake of brevity, we call these groups *regular* and *irregular*.

Previous studies testing the SS and DS approaches on Russian

- Behavioral studies on Russian looked at adult native speakers, L1acquisition in norms and in SLA children, in L2 learners and subjects with various neurological and developmental deficits (e.g. Chernigovskaya et al. 2007; Gor 2003, 2010; Gor and Chernigovskaya 2001, 2003, 2005; Gor and Jackson 2013; Gor et al. 2009; Svistunova 2008). The findings did not unambiguously support either DS or SS approach.

- For example - adults were shown to use the most frequent AJ class pattern as the default one, although Russian has several highly frequent productive verb classes. It was often applied to nonce verbs irrespective of their morphonological properties. On the other hand, children overgeneralize several conjugational patterns in the course of acquisition, and the same was true for SLI children in contrast with the English data.

- The predictions of the SS and DS theories were tested on Russian in our studies. We looked at adult native speakers, L1 and L2 learners and subjects with various neurological and developmental deficits. Participants were provided with infinitives or past tense forms of real or nonce verbs and prompted to generate 1Sg and 3Pl present tense forms.
- Healthy adult native speakers showed a strong tendency to overgeneralize the AJ class pattern. In particular, they applied it to the nonce verbs ending in *–ili* *and–yli* (no real verbs have this conjugational pattern). <u>This is in conflict with the SS theory.</u>

- 4-year-old children also heavily rely on the AJ class pattern. But gradually, other patterns become more active. For example, around the age of 5 children stop making mistakes with OVA class verbs and actively overgeneralize this pattern.
- The generalizations made in the studies of English-speaking subjects with SLI (specific language impairment), aphasiac deficits and Alzheimer disease (e.g. Ullman et al., 1997b) that supported the DS approach also were not borne out in Russian.

- As a result, we argue that Yang's (2002) model relying on multiple rules of different status might be better suited to account for the known findings. A similar model for Russian was developed by Gor (2003).

Words used in the our fMRI study

	AJ		11th class
infinitive form	*čitát'* - 'to read'	infinitive form	*spat'* - 'to sleep'
1Sg present tense form	*čitá-j-u* – 'I read' (-j- suffix is added)	1Sg present tense form	*splju* - 'I sleep';
		infinitive form	*klast'* -'to put';
		1Sg present tense form	*kladu* - 'I put'

Behavioral experiments by Chernigovskaya, Gor and colleagues:

AJ class also behaves as the default class (the pattern is overgeneralized not depending on phonological similarity etc.).

Regular

Irregular

FMRI study

Stimuli for our fMRI study

Stimuli types (35 words in each list) :

1. regular verbs,
2. irregular verbs,
3. regular nonce verbs,
4. irregular nonce verbs,

Balanced in terms of:

- length
- syllabic structure
- word frequency

[1] Nonce words mimick the general characteristics of the corresponding real word group, but we tried to avoid close resemblance to particular real words. So no one-to-one pairing between real and nonce stimuli can be made, and the latter are listed in alphabetical order (according to the Russian alphabet).

Frequencies (in instances per million) are taken from (Lyashevskaya & Sharoff, 2009).

The A class model can also be applied to these nonce verbs (e.g. *atat' – aču*), and a couple of them are compatible with the ZHA class (e.g. *fažat' – fažu*).

	real infinitive	present tense 1SG form	length	F	nonce infinitive	present tense 1SG form	length
1	čitat'	čitaju	6	315.5	atat'	ataju	6
2	igrat'	igraju	6	249.6	betat'	betaju	6
3	mešat'	mešaju	6	116.0	brijat'	brijaju	6
4	želat'	želaju	6	115.6	vogat'	vogaju	6
5	padat'	padaju	6	107.8	vupat'	vupaju	6
6	terjat'	terjaju	6	79.2	gemat'	gemaju	6
7	guljat'	guljaju	6	70.9	gyrjat'	gyrjaju	6
8	letat'	letaju	6	66.3	dagat'	dagaju	6
9	menjat'	menjaju	6	58.7	dopat'	dopaju	6
10	sijat'	sijaju	5	45.9	žitat'	žitaju	5
11	šagat'	šagaju	6	44.4	zenjat'	zenjaju	6
12	lomat'	lomaju	6	40.5	zotat'	zotaju	6
13	kivat'	kivaju	6	39.1	zuljat'	zuljaju	6
14	pugat'	pugaju	6	31.9	imlat'	imlaju	6
15	rugat'	rugaju	6	29.5	ifat'	ifaju	6
16	kušat'	kušaju	6	25.7	ketat'	ketaju	6
17	kidat'	kidaju	6	22.9	kibat'	kibaju	6
18	sažat'	sažaju	6	22.5	lubat'	lubaju	6
19	kopat'	kopaju	6	19.6	madat'	madaju	6
20	vešat'	vešaju	6	19.0	mijat'	mijaju	6
21	rydat'	rydaju	6	18.3	mjapat'	mjapaju	6
22	vlijat'	vlijaju	6	17.9	nalat'	nalaju	6
23	migat'	migaju	6	17.4	nydat'	nydaju	6
24	gadat'	gadaju	6	17.1	ozat'	ozaju	6
25	topat'	topaju	6	17.0	pelat'	pelaju	6
26	putat'	putaju	6	16.7	ruvat'	ruvaju	6
27	ronjat'	ronjaju	6	15.2	somat'	somaju	6
28	motat'	motaju	6	14.8	tonjat'	tonjaju	6
29	zevat'	zevaju	6	13.8	fažat'	fažaju	6
30	kapat'	kapaju	6	13.3	ferjat'	ferjaju	6
31	kusat'	kusaju	6	12.7	xipat'	xipaju	6
32	nyrjat'	nyrjaju	6	9.6	xutat'	xutaju	6
33	axat'	axaju	5	4.8	cadat'	cadaju	5
34	oxat'	oxaju	5	4.7	čevat'	čevaju	5
35	ikat'	ikaju	5	3.6	šulat'	šulaju	5
Average			5.9	49.1			5.9

	real infinitive	present tense 1SG form	length	F	nonce infinitive	present tense 1SG form	length
1	brat'	beru	5	302.3	basti	basu, bastu	6
2	spat'	splju	5	246.2	bezt'	bezu	6
3	bežat'	begu	6	221.8	bryt'	broju, bryvu	6
4	nesti	nesu	5	124.1	vlyzt'	vlyzu	6
5	kolot'	kolju	6	112.3	vrjast'	vrjadu, vrjanu	6
6	lezt'	lezu	5	78.7	gesti	gesu, getu, gedu, gebu	6
7	rasti	rastu	5	71.7	glyt'	gloju, glyvu	6
8	vrat'	vru	5	69.8	dlesti	dlesu, dletu, dledu, dlebu	6
9	plyt'	plyvu	5	55.7	dljast'	dljadu, dljanu	5
10	gnat'	gonju	5	49.1	dorot'	dorju	6
11	polzti	polzu	6	48.2	žasti	žasu, žastu	6
12	klast'	kladu	6	44.4	žlyt'	žloju, žlyvu	6
13	rvat'	rvu	5	38.4	zgat'	zgu	6
14	trjasti	trjasu	6	31.2	koloč'	koloku, kolku	6
15	revet'	revu	6	27.0	krat'	kru	6
16	bresti	bredu	6	19.0	krjasti	krjasu, krjatu, krjadu	6
17	lgat'	lgu	5	16.5	lpat'	lpu	6
18	teret'	tru	6	14.8	mkat'	mku	6
19	gryzt'	gryzu	6	13.2	mljast'	mljadu, mljanu	6
20	cvesti	cvetu	6	10.8	mresti	mresu, mretu, mredu, mrebu	6
21	gresti	grebu	6	9.5	nolot'	nolju, nelju	6
22	drat'	deru	5	9.2	nrast'	nradu	6
23	krast'	kradu	6	7.3	prast'	pradu	6
24	porot'	porju	6	7.3	resti	resu, retu, redu, rebu	6
25	plesti	pletu	6	6.6	sulzti	sulzu	6
26	kljast'	kljanu	6	4.9	tlast'	tladu	6
27	molot'	melju	6	4.8	tolot'	tolju, telju	6
28	pasti	pasu	5	4.1	flat'	flu	6
29	brit'	breju	5	4.0	xnesti	xnesu, xnetu, xnedu, xnebu	6
30	kryt'	kroju	5	4.0	xorot'	xorju	6
31	mesti	metu	5	3.1	cvat'	cvu	6
32	polot'	polju	6	1.8	čvast'	čvadu	5
33	tkat'	tku	5	1.8	člyt'	čloju, člyvu	5
34	prjast'	prjadu	6	1.0	švat'	švu	5
35	toloč'	tolku	6	1.0	šolot'	šolju, šelju	5

- Subjects were 21 native speakers of Russian (13 women), 19-32 years of age, with no history of neurological or psychological disorders. All participants were right-handed, as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). Subjects were given no information about the specific purpose of the study. All procedures were in accordance with the declaration of Helsinki and were approved by the Ethics Committee of the Institute of the Human Brain, Russian Academy of Sciences.

Language protocol and experimental fMRI paradigm

- Stimuli were presented for 700 ms on a screen mounted inside the magnet just in front to the subjects’ eyes. We used varied ISI by presenting fixation crosses (“xxxxx”) between stimuli for 3100, 3200, 3300, 3400 or 3500 ms. Additionally, 280 stimuli were pseudo-randomly intermixed with 140 “null-events” (fixation crosses) for attaining baseline level of a signal between

Data analysis

Preprocessing and statistical GLM analysis was performed with SPM 8.

«Full Factorial» was applied for group random effect analysis of BOLD data:

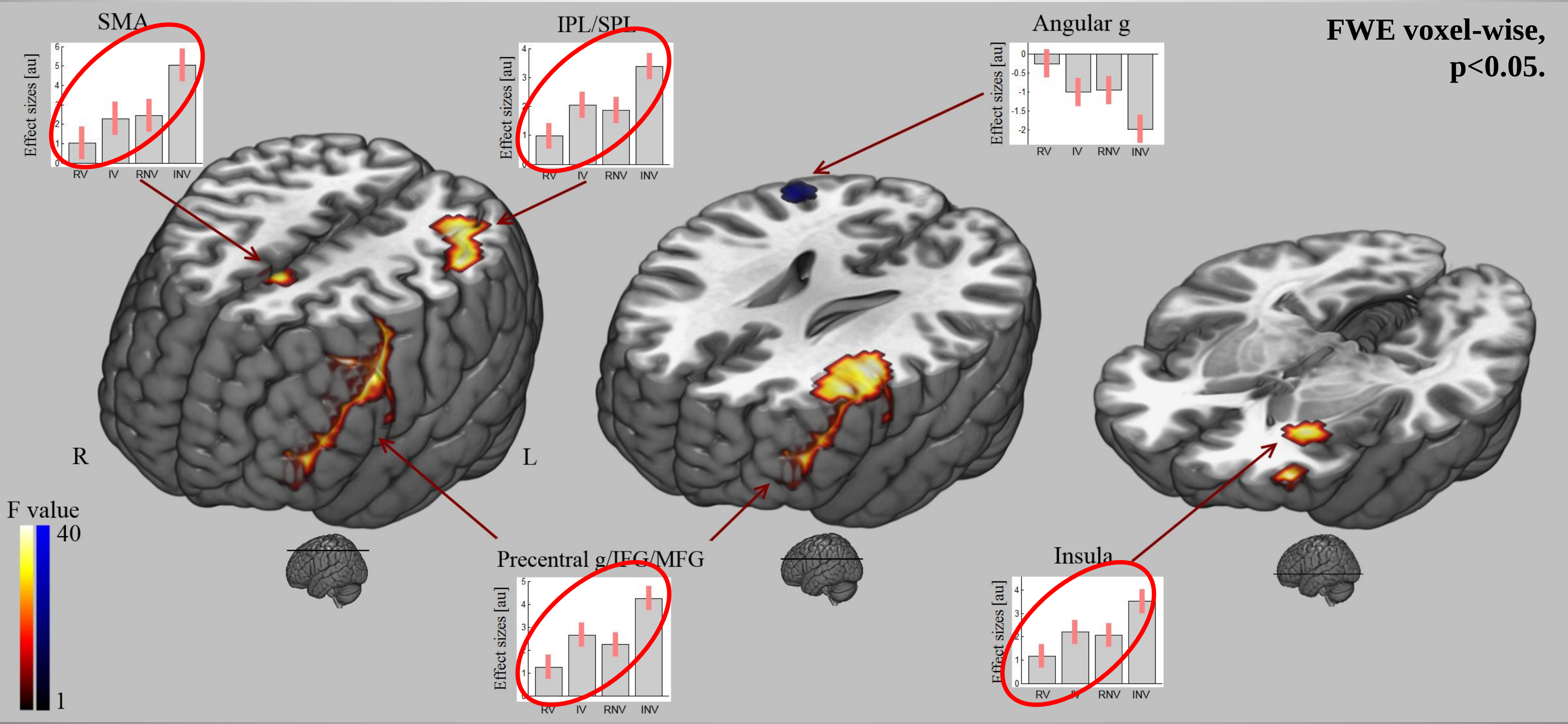
	Regularity	
Lexicality	**Regular verbs (RV)**	**Irregular verbs (IV)**
	Regular nonce verbs (RNV)	**Irregular nonce verbs (INV)**

- We subjected our data to whole brain voxel-wise analysis of context dependent changes in functional connectivity (a psychophysiological interaction (PPI) analysis). Firstly, we found that functional connectivity between the left inferior frontal gyrus (LIFG) and bilaterally distributed clusters in the superior temporal gyri was significantly greater in regular real verb trials than in irregular ones.

- Secondly, we observed a significant positive covariance between the number of mistakes in irregular real verb trials and the increase in functional connectivity between LIFG and the right anterior cingulate cortex in these trails as compared to regular ones. Thus, we could dissociate regularity and processing difficulty effects.

Main effect of 'Regularity' in Verbs

Regular real (**RV**) + nonce verbs (**RNV**) vs. Irregular real (**IV**) + nonce verbs (**INV**)



Similar pattern was observed for the main effect of "Lexicality". "Lexicality"× "Regularity" interaction was not significant.

Slioussar N., Kireev M., Chernigovskaya T., Kataeva G., Korotkov A., Medvedev S. (2014). ***Brain and Language*.**

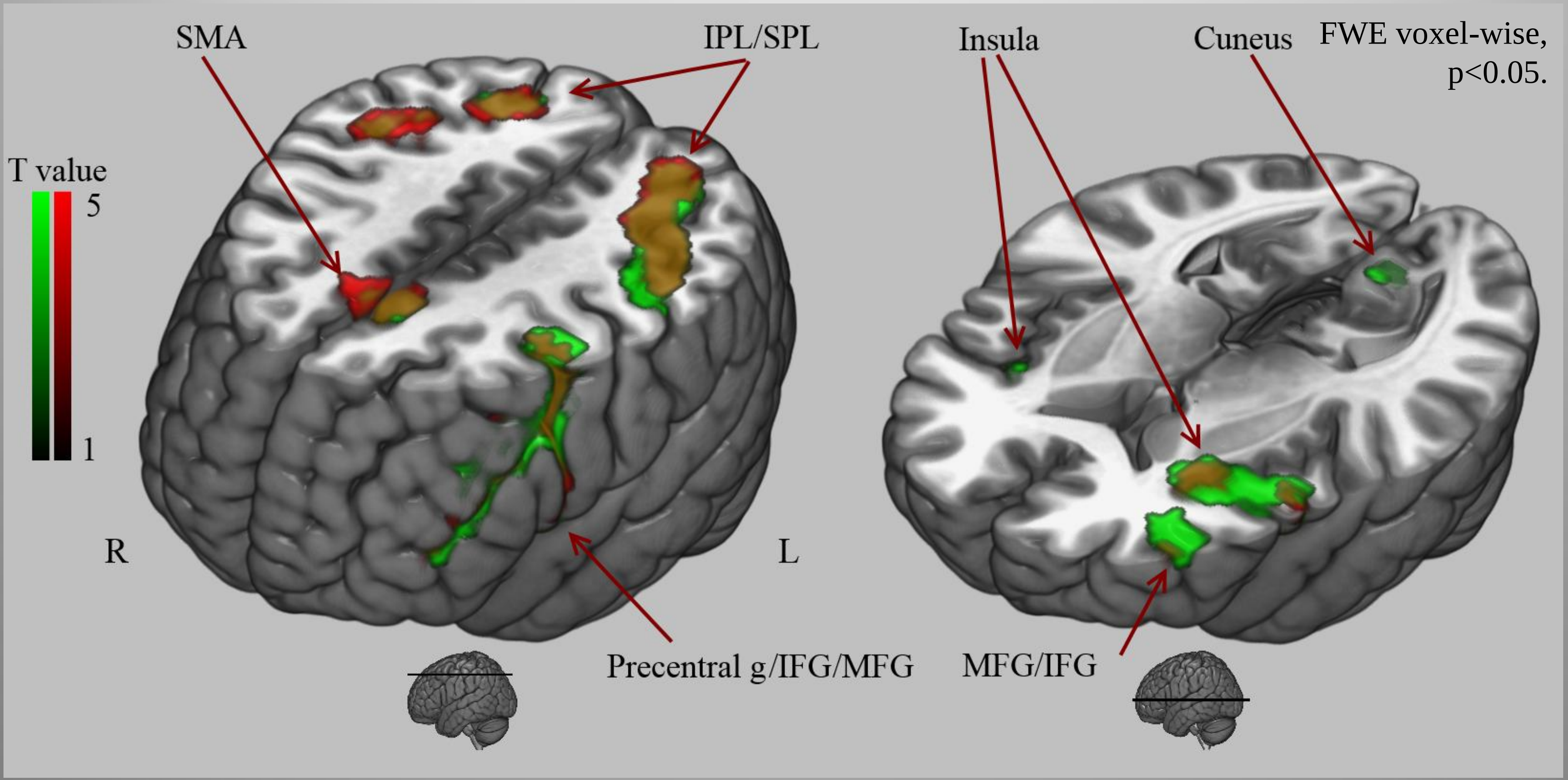
Parametric contrast

T-contrast to model an increase in processing load:

(**RV**>B)<(**IV**>B)<(**RNV**>B)<(**INV>B)** – **denoted by red**

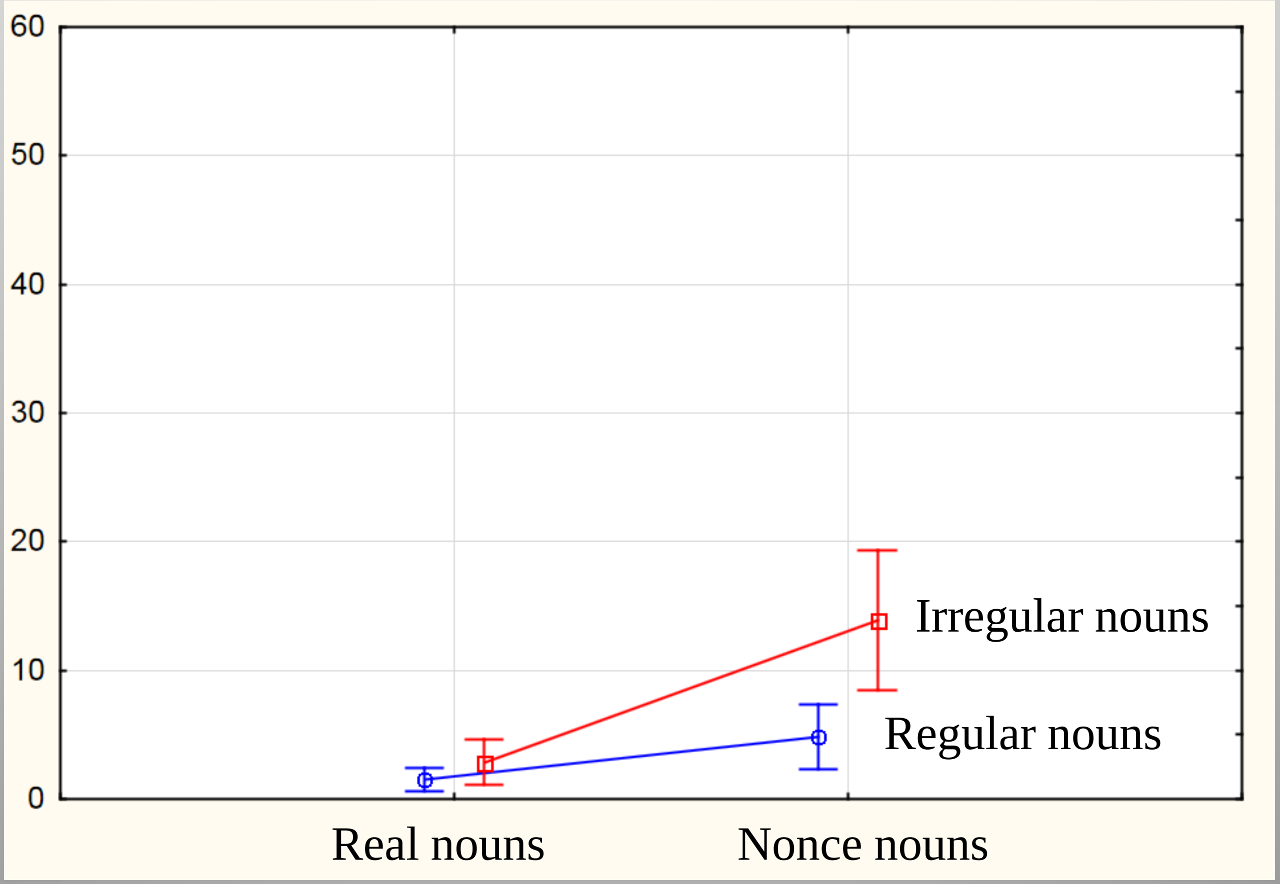
(**RN**>B)<(**IN**>B)<(**RNN**>B)<(**INN**>B) – denoted by green

B is baseline condition

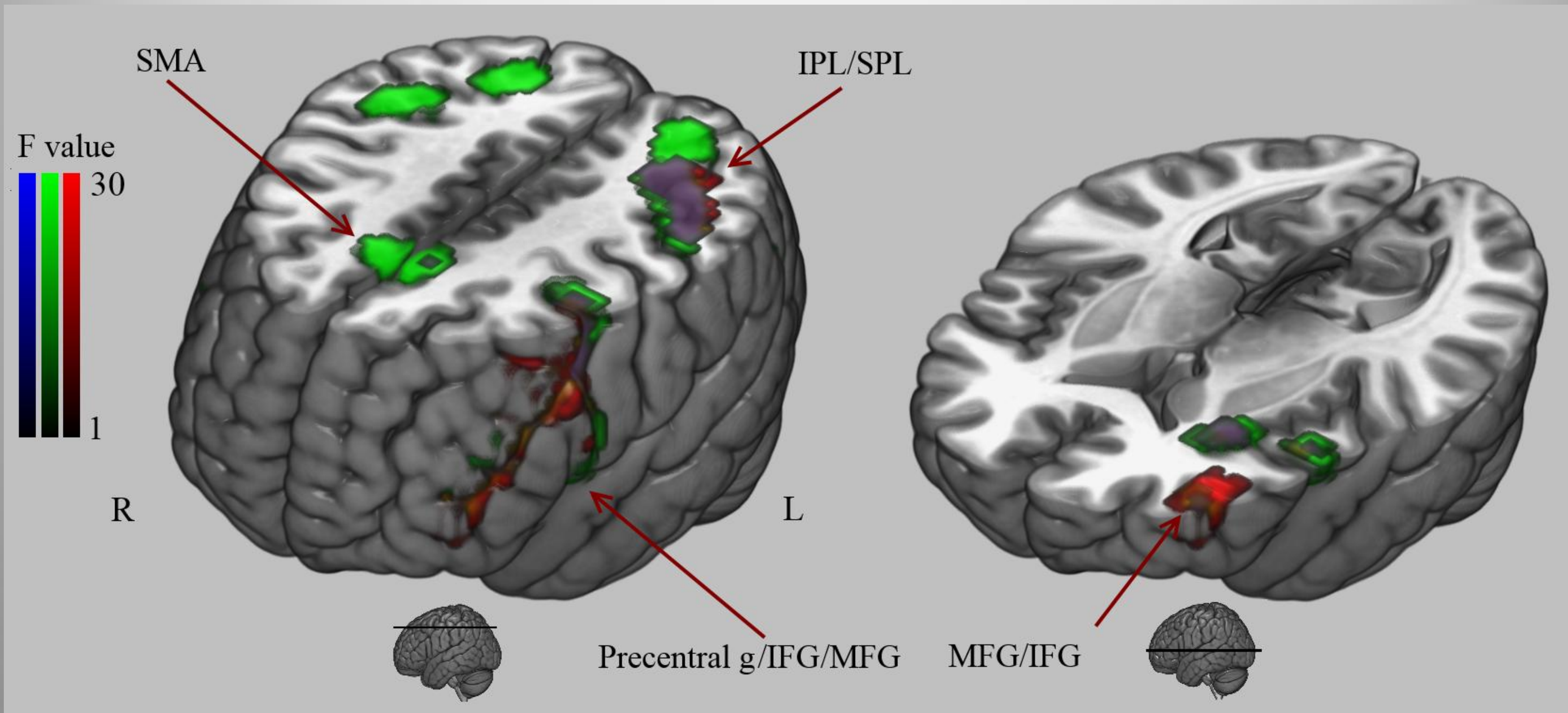


Slioussar N., Kireev M., Chernigovskaya T., Kataeva G., Korotkov A., Medvedev S. (2014). ***Brain and Language*****.**

Behavioral data. Number of mistakes



Overlap between 'Regularity' and 'processing difficulty' effects - Verbs.



1. Red – main effect of "Regularity".
2. Green – areas sensitive to increase in processing load

Blue – conjunction between 1 and 2

Slioussar N., Kireev M., Chernigovskaya T., Kataeva G., Korotkov A., Medvedev S. (2014). *Brain and Language*.

Interaction between competent brain areas

Psychophysiological interactions (PPI) measures the interaction between brain regions at the neuronal level (based on estimated changes in neuronal activity) and allows to assess if a functional coupling between two brain areas sensitive to difference between experimental tasks

Previous PPI studies

ELSEVIER

NeuroImage

www.elsevier.com/locate/ynimg
NeuroImage 28 (2005) 115 – 121

Cingulate control of fronto-temporal integration reflects linguistic demands: A three-way interaction in functional connectivity

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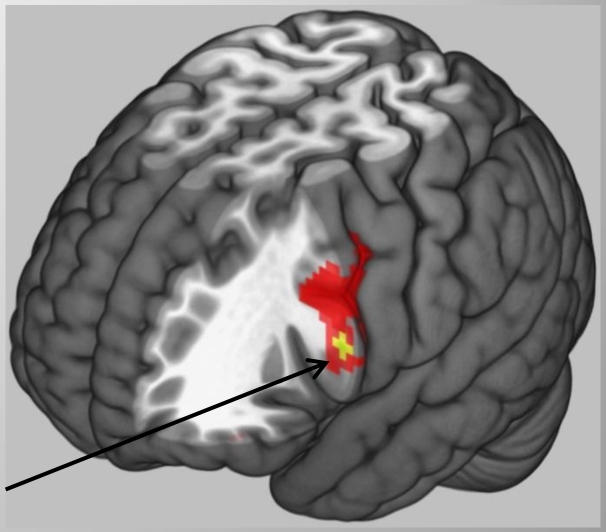
One of the main results – passive processing of regular verbs associated with increased connectivity within the left fronto-temporal neural system governed by anterior cingulate cortex.

Current PPI analysis

ROI selection.

Based on peak maximum of the left IFG cluster induced by significant factor "Regularity".



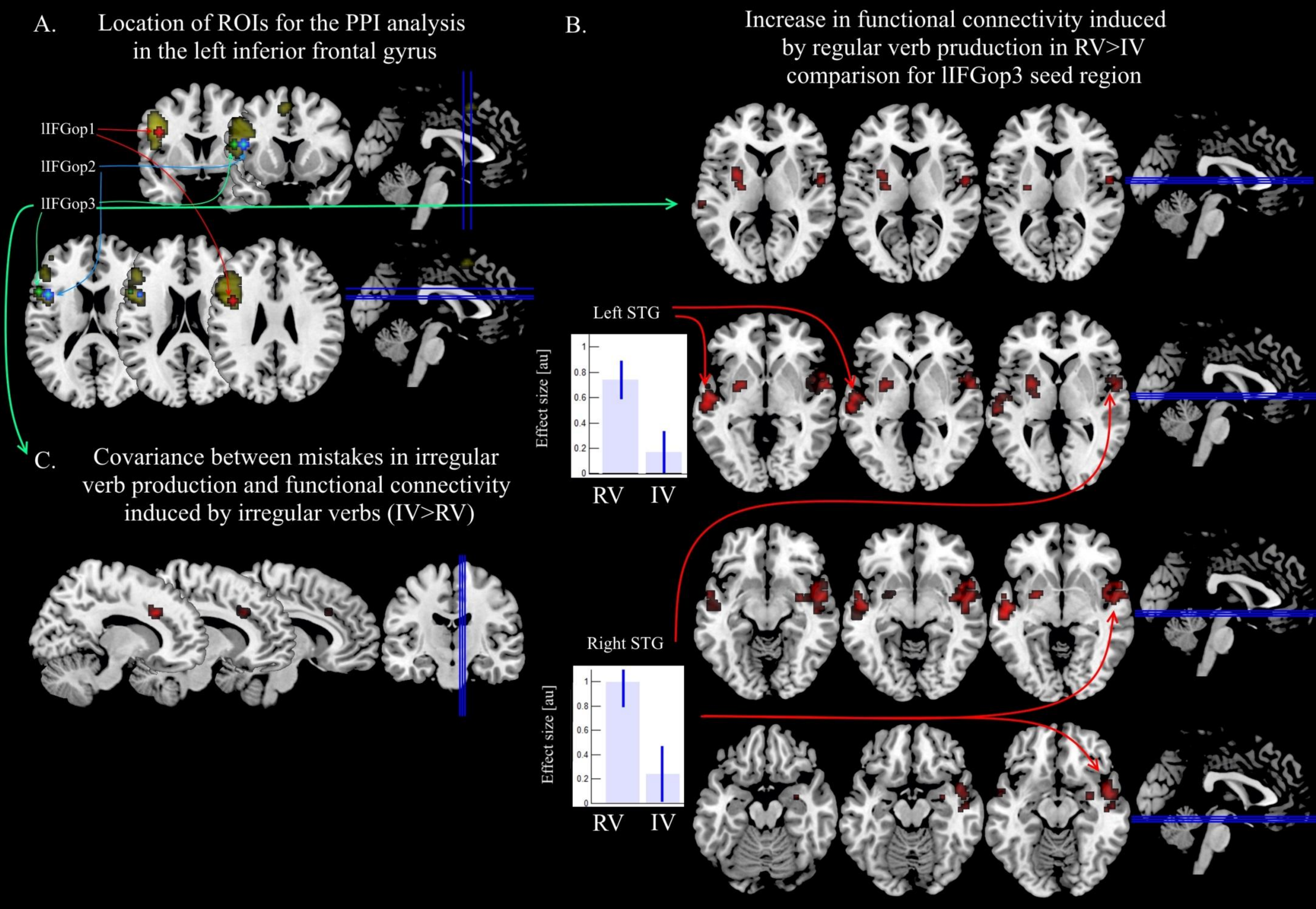
ROI: sphere with 4 mm radius (BA 44/45)

Group level statistical analysis:
One sample t-test RV > IV.

Whole brain voxel-wise PPI-analysis, uncorrected threshold ($p<0.001$) and subsequent correction at the cluster level (FWE $p<0.05$)

PPI-data

	Subtractive analysis: greater activity within the fronto-pariental network (including left IFG area) for…	**PPI analysis:** greater connectivity between left IFG and temporal brain network for…	**Task:**
'The Cambridge group'	**regular verbs** (Tyler & al. 2005)	**regular verbs** (Stamatakis et al., 2005) **left lateralized processing**	**Auditory** modality. Phonological similarity judgment
Our group	**irregular** stimuli, **nonce** stimuli	**regular verbs** **bilateral**	**Visual** modality **Oral production**


A.
Location of ROIs for the PPI analysis in the left inferior frontal gyrus
lIFGop1
lIFGop2
lIFGop3
B.
Increase in functional connectivity induced by regular verb pruduction in RV>IV comparison for lIFGop3 seed region
Left STG
Effect size [au]
1
0.8
0.6
0.4
0.2
0
RV
IV
Right STG
Effect size [au]
1
0.8
0.6
0.4
0.2
0
RV
IV
C.
Covariance between mistakes in irregular verb production and functional connectivity induced by irregular verbs (IV>RV)

- Now, what does this mean for the DS and SS approaches? In the SS approach, only the frequency of a morphological pattern really matters. The canonical version of the DS approach postulates one default rule and argues that all other forms are stored in the memory.

- Russian irregular verbs must undergo morphological decomposition (at least to get rid of the infinitival affix), and some combination of morphological analysis and memory retrieval processes makes them more difficult than regular stimuli on a certain scale, while English irregular stimuli are the easiest on this scale because no morphological analysis is required at all. Potentially, hybrid models with several rules of different status are better suited for the data

- In contrast to recent functional connectivity studies arguing for the independence of language-related and domain-general cognitive control systems (Blank et al., 2014), our data demonstrate how these systems can be functionally integrated.

- To summarize, our data complements the only existing PPI study of inflectional morphology (Stamatakis et al., 2005). The results of the functional connectivity analysis absolutely could not be predicted from the functional activity analysis in our case. We not only observed the processing difficulty effect we identified earlier in 2014, but could also find a novel effect of regularity.

Concluding remarks

While the level of functional activity in the left IFG is sensitive to processing demands which are greater for irregular verbs, the functional connectivity between the left IFG and the temporal cortex is more critical for the regular verb production.

Our findings stress the importance of bilaterally integrated temporal subsystem and undermine the idea about the unique role of left fronto-temporal cortex for regular form processing.

- What is it all about? – It’s to understand how brain manages the mind and especially the language. How mental lexicon and grammar function, e.g. do we store morphologically complex words as whole units or we construct them every time? Do we really compute some procedures according to symbolic rules of the Chomsky-Pinker type and extract the other forms from associative memory? What’s the role of probabilities – type and token frequencies, lexical family frequencies? What about real usage frequencies for L1 acquisition (no data in no languages),etc.

- Never-ending discussions in language acquisition, development and processing continue to stay between the two poles:
- (1) Language is a separate module, most possibly inborn, based on symbolic rules not governed by probabilities
- (2) Language is just one of a set of higher cognitive functions, probabilities playing the crucial role tuning the neuronal nets

NB: separation of linguistic and more general cognitive functions is extremely difficult in imaging research – the effect of increase in cognitive load can not be neglected

- And the last but not the least:

Cross-linguistic studies are most important if we want to extrapolate the data to Human language faculty

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Thank you for your attention!