Influence of competition conditions on ERP components during creative thinking

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2022

РНФ 22-28-02012

Social beings

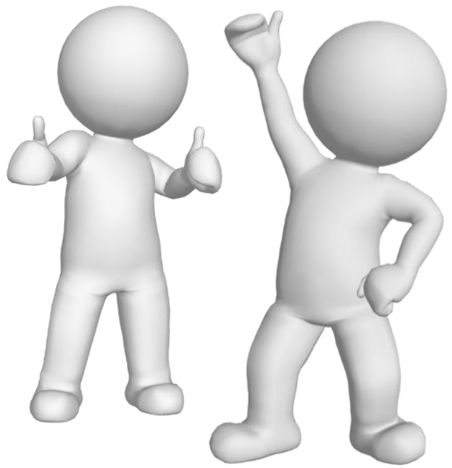
solve a lot of tasks in conditions of social interaction

And it matter with whom to interact☺ Hu et al.,2018

Modes of solving problems in social interaction

COMPETITION

COOPERATION



Paradigms

SOCIAL INTERACTION

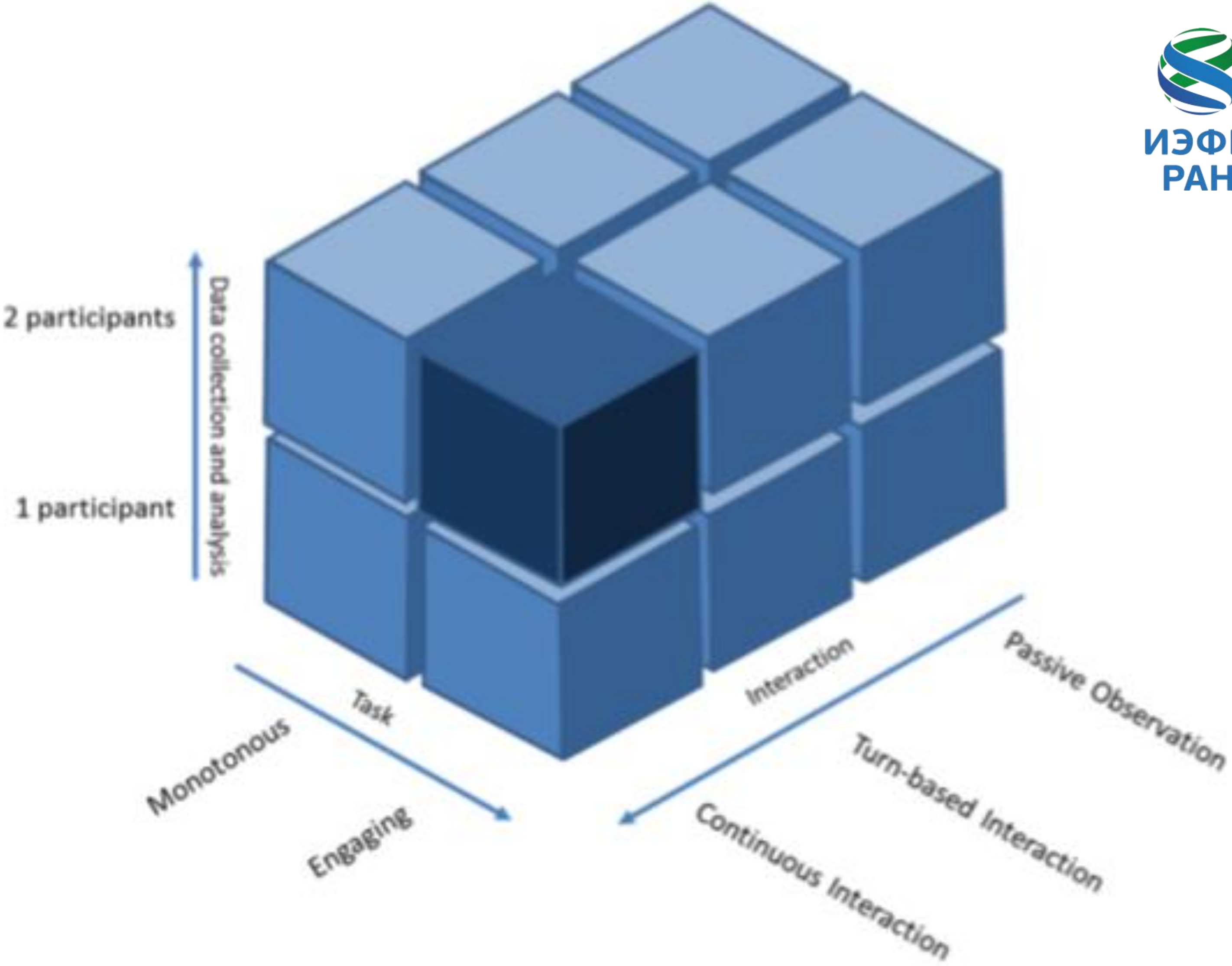


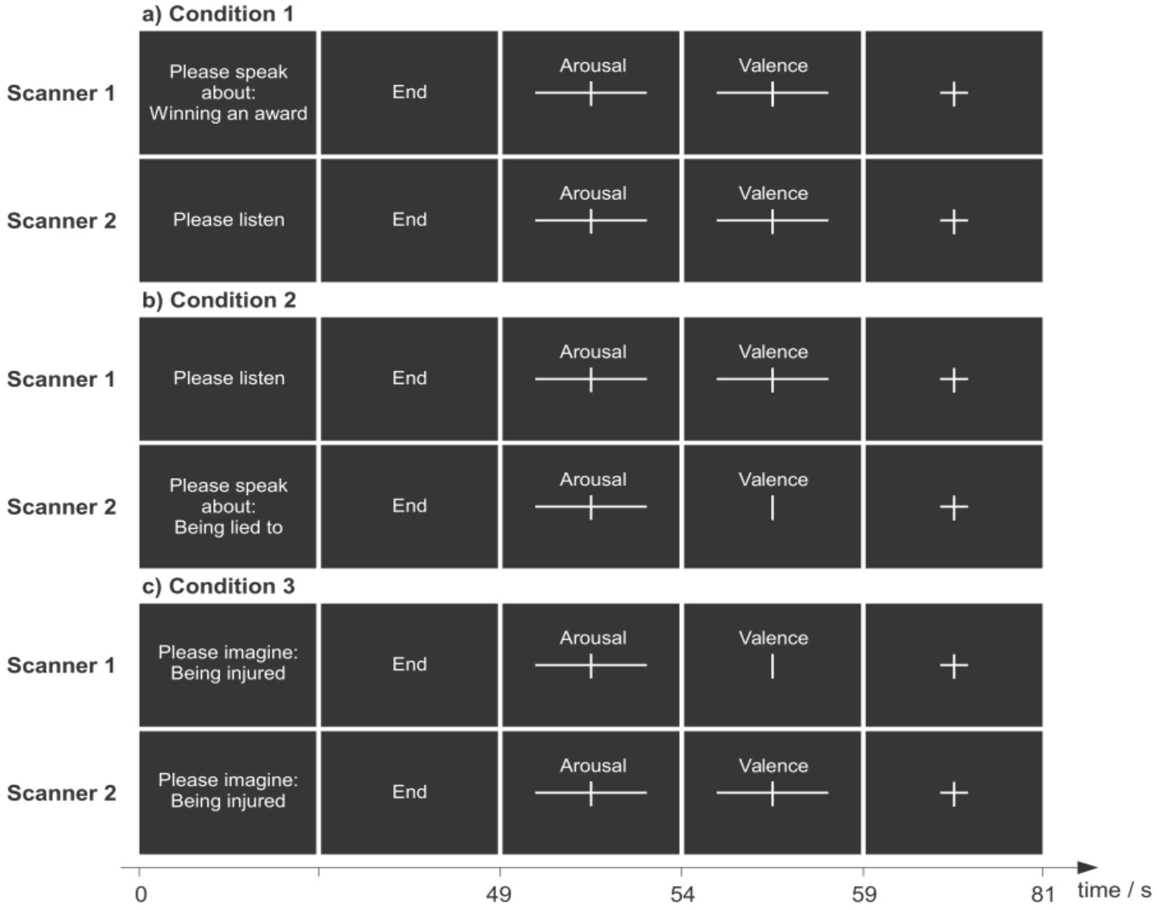
FIGURE 2 | Representation of the experimental 'landscape' of the two-person neuroscience. Rearranged from Schilbach et al. (2012).

COMMUNICATION

Interindividual synchronization of brain activity during live verbal communication

Kai Spiegelhalder[a,*,1], Sabine Ohlendorf[b,1], Wolfram Regen[a], Bernd Feige[a], Ludger Tebartz van Elst[a], Cornelius Weiller[c], Jürgen Hennig[b], Mathias Berger[a], Oliver Tüscher[a,c,d]

Behavioural Brain Research 258 (2014) 75–79



SCANNERS: 2 x 3T Trio

ANALYSIS: ROI-based between-brain correlation of shifted time series

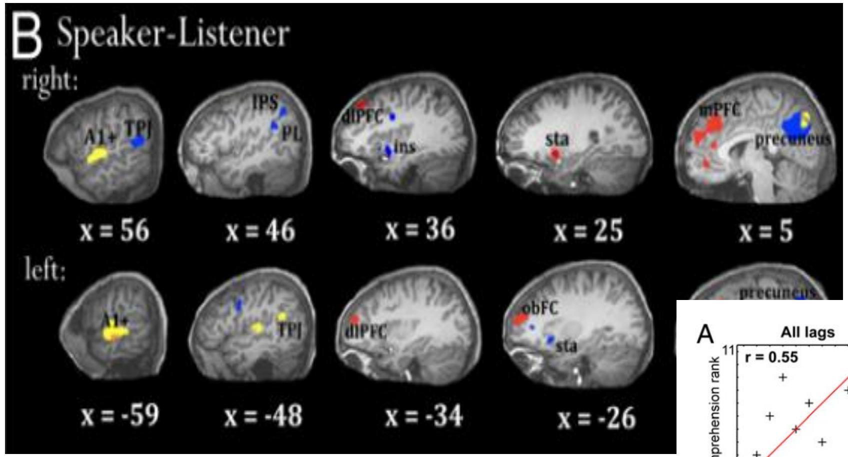
Speaker–listener neural coupling underlies successful communication

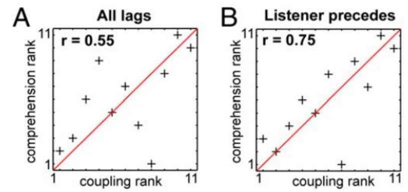
Greg J. Stephens[a,b,1], Lauren J. Silbert[c,1], and Uri Hasson[c,d,2]

PNAS | August 10, 2010 | vol. 107 | no. 32

SCANNER: 3T Allegra, one "speaker", "several listeners"

ANALYSIS: Voxel-wise between-brain time-lagged regression





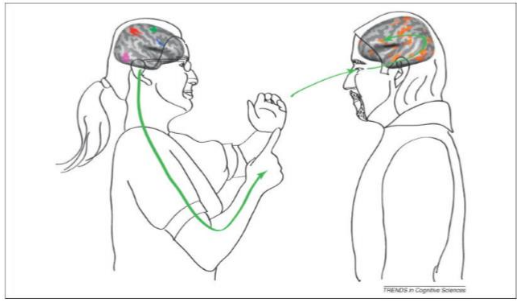
Mapping the information flow from one brain to another during gestural communication

Marleen B. Schippers[a], Alard Roebroeck[b], Remco Renken[a], Luca Nanetti[a], and Christian Keysers[a,c,1]

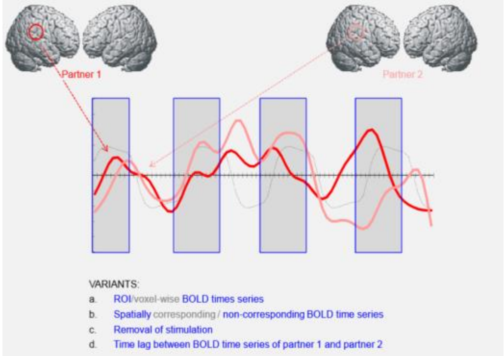
PNAS | May 18, 2010 | vol. 107 | no. 20 |

SCANNER: 3T Philips, "gesturer"-"guesser" dyads, partners switch roles

ANALYSIS: ROI-based between-brain Granger causality



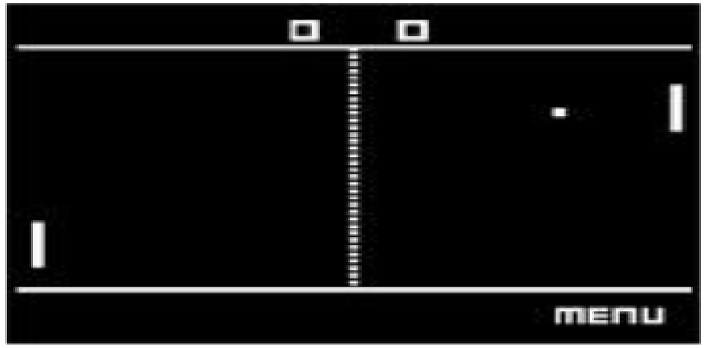
from Hasson et al., 2011 TICS



GAME MODELS

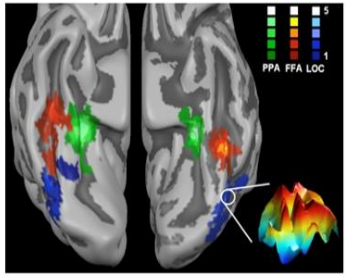
"BOLD brain pong"

2 people



Joint attention and self-regulation of BOLD-activity in real time of social interaction (60-80% success)

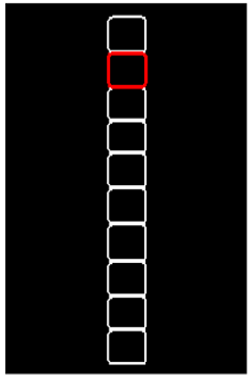
Real-Time Multi-Voxel Pattern Classification (rt-MVPC)



Rainer Goebel

Neurofeedback display

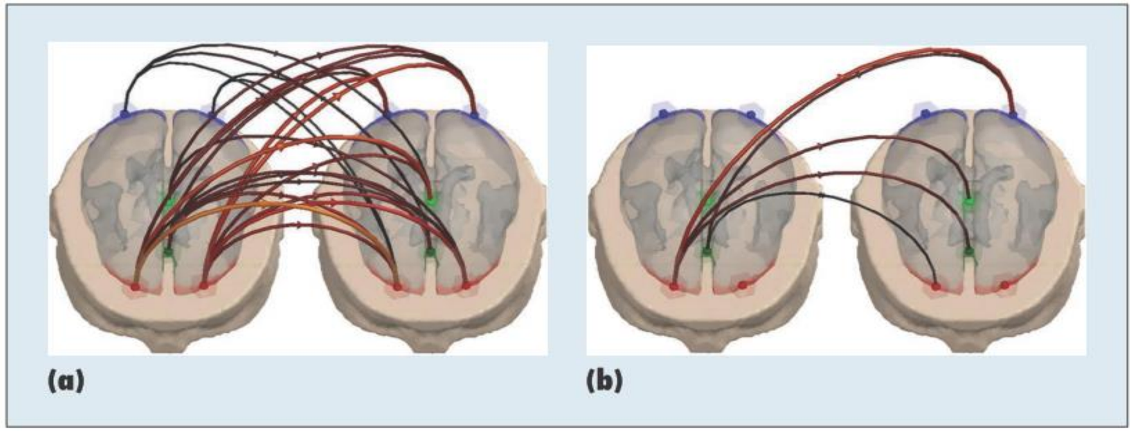
- "Thermometer" visualization of target level and ROI activity
- Easy to interpret by subjects
- Continously updated gradual feedback
- Immediate feedback max. 1 second after data acquisition



Goebel R, Sorger B, Kaiser J, Birbaumer N, Weiskopf N (2004) "BOLD brain pong: self-regulation of local brain activity during synchronously scanned, interacting subjects." *34th Annual Meeting of the Society for Neuroscience*

Deception game

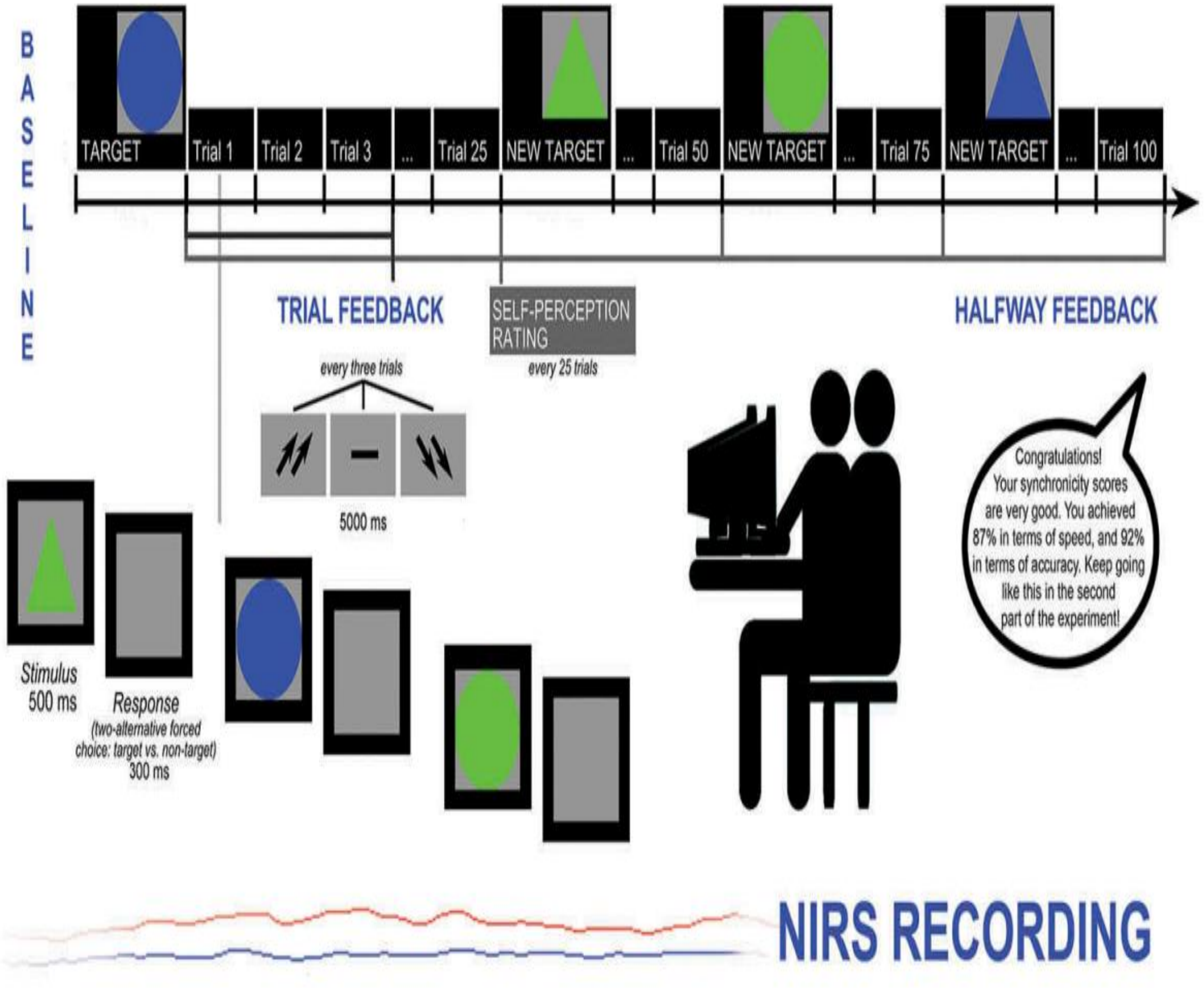
A setup of an EEG hyperscanning during a card game.

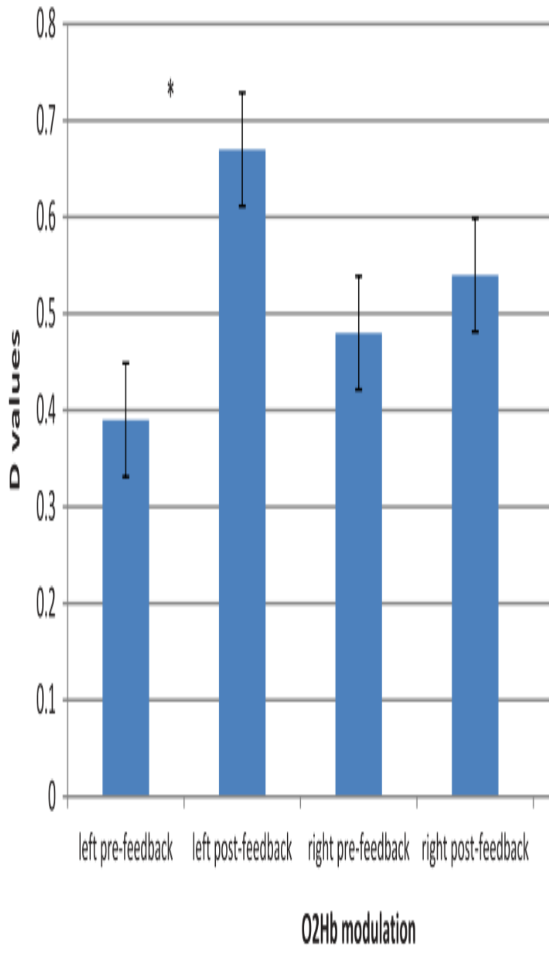


(a) a pure-cooperative (b) a pure-defect behavior

Astolfi et al., IEEE Intell Syst. 2011, doi: 10.1109/MIS.2011.61

Interbrains cooperation: Hyperscanning and self-perception in joint actions





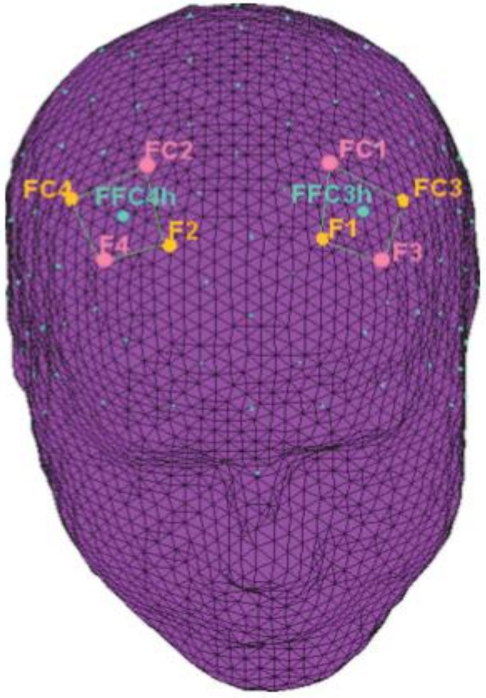


Figure 2. The location of NIRS (near-infrared spectroscopy) channels. The emitters were placed on channel position FC3–FC4 and F1–F2, while detectors were placed on FC1–FC2 and F3–F4. To view a color version of this figure, please see the online issue of the Journal.

Balconi M, Vanutelli ME

JOURNAL OF CLINICAL AND EXPERIMENTAL NEUROPSYCHOLOGY, 2016
http://dx.doi.org/10.1080/13803395.2016.1253666

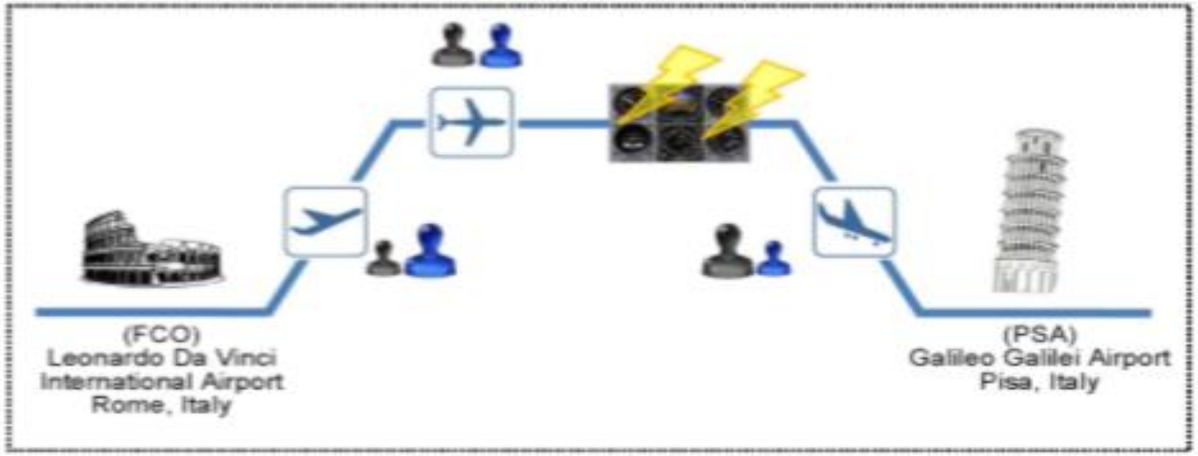
REAL DEEDS

Simulator Flights

Alstofi et al,2010;
Toppi et al.,2016

a)

b)



ART

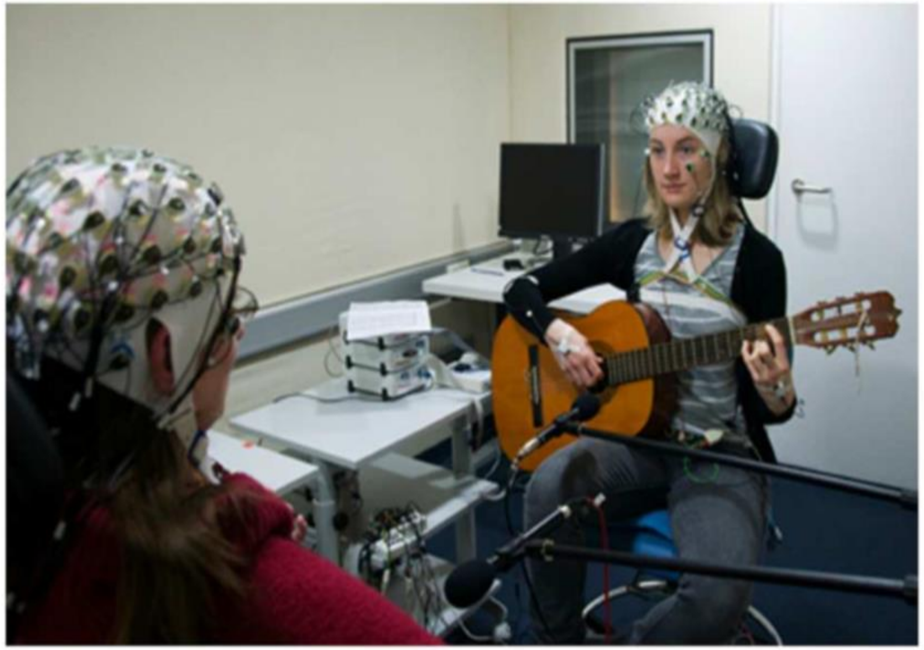
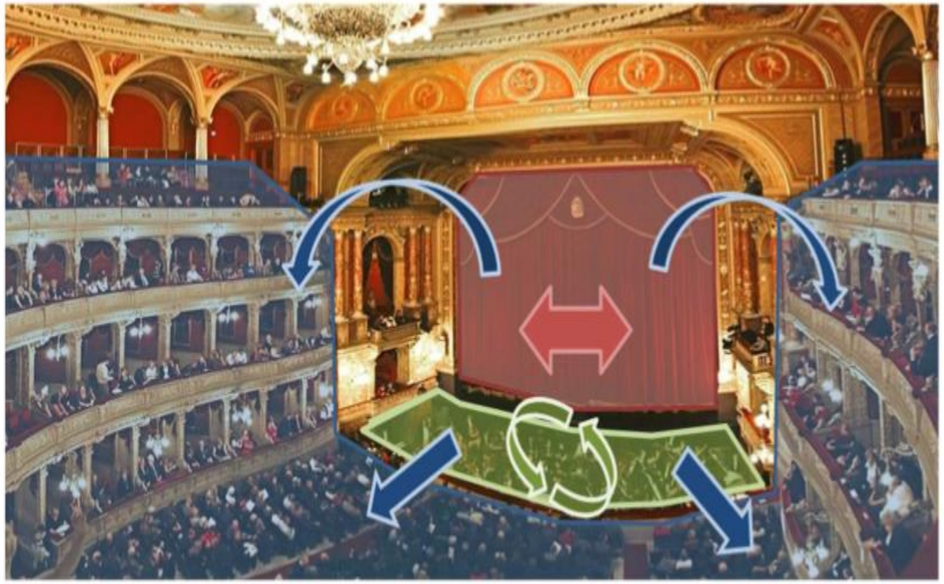


FIGURE 3 | Advantages of EEG as a neuroimaging modality. From Sänger et al. (2012). The experiment from Sänger et al. (2012)



Michael Acquadro et al., 2016, 10, pp.242.

Social interaction in an ecological way with a socially engaging task (Sanger et al., 2012).

- see each other’s face,
- enabling them to perceive each other’s gaze
- and facial expressions,
- crucial social cues in human interactions (empathy, theory of mind).

MAIN FEATURES FOR ANALYSIS

TABLE 1 | Summary of devices, types of stimuli, types of interaction, and methods of analysis used in hyperscanning studies.

	Device	Experimental paradigm	Interaction	Method of analysis	Reference
Less ecological	fMRI x2	Trust game	Turn-based	Coherence	Montague, 2002
	NIRS x2	Button pressing, cooperation/competition	Turn-based: trials	Wavelet transform coherence	Cui et al., 2012
	EEG x2	Prisoner's dilemma	Turn-based	Granger's causality	Babiloni et al., 2007
	EEG x2	Chicken's game	Turn-based	Directed transfer function, partial directed coherence	Astolfi et al., 2010
	EEG x2	Speech rhythm	Turn-based	Wavelet transform, cross-correlation analysis	Kawasaki et al., 2013
	EEG x2	Finger tapping	Continuous	Power spectra analysis (no inter-brain analysis)	Tognoli et al., 2007
	EEG x2	Finger movement	Continuous	Phase synchrony and behavioral analysis	Yun et al., 2012
	EEG x2	Hands movement	Continuous	Phase locking value	Dumas et al., 2010
More ecological	fMRI (no hyperscanning)	Natural movie viewing	Observation	Correlation of hemodynamic waveform	Hasson et al., 2004
	EEG x4	Card Game	Turn-based	Partial directed coherence	Babiloni et al., 2006
	EEG x2	Plane operating	Continuous	Partial directed coherence	Astolfi et al., 2011a
	EEG x4	Saxophone playing	Continuous	Frequency analysis (TRPD/TRPI) and correlation with empathy	Babiloni et al., 2012
	EEG x2	Guitar playing	Continuous	Phase Locking Index and inter-brain phase coherence	Lindenberger et al., 2009
	EEG x2	Romantic kissing	Continuous	Graph theory analysis, Adaptive Integrative Coupling Index	Müller and Lindenberger, 2014

MODELS FOR SOCIAL INTERACTIONS

G Model
NBR-1608: No. of Pages 18

Table 1
List of the analyzed studies performed with hyperscanning methodologies.

Research area	Authors, journal, year	Task instructions	Number of subjects	Subjects × method	Results
Neuroeconomy	Montague et al., 2002, Neuroimage	Handy-Dandy: the sender see one of two color on the screen and sent one of two colors to the receiver. The receiver have to say if the color sent by the sender correspond to the color the sender saw before or not	6	2 × fMRI	A cluster of activity is identified in the region of the supplementary motor area, but this is stronger in the Sender than in the receiver
Neuroeconomy	King-Casas et al., 2005, Science	Trust Game	96	2 × fMRI	Results suggest that the head of the caudate nucleus receives or computes information about (i) the fairness of a social partner's decision and (ii) the intention to repay that decision with trust
Neuroeconomy	Tomlin et al., 2006, Science	Trust Game	200	2 × fMRI	(i) agent-specific response types localized on the medial bank of cingulate cortex, (ii) a systematic spatial variation of each response type across the anterior-posterior axis of cingulate cortex, and (iii) a dependence of both signals on the presence of a responding agent.
Neuroeconomy	Chiu et al., 2008, Neuron	Trust Game	30	2 × fMRI	Showed that high-functioning males with autism spectrum disorder exhibit a severely diminished cingulate self-response when playing the game with a human partner.
Neuroeconomy	Fliessbach et al., 2007, Science	Simple performance lead to a monetary reward that were compared on-line by both subjects scanned	33 (38 recorded)	2 × fMRI	This study shows a relationship between relative income and hemodynamic responses in the ventral striatum. Receiving less than another subject was associated with a reduced BOLD signal in this area
Neuroeconomy	Babiloni et al., 2007, Conference Proceedings – IEEE Engineering in Medicine and Biology Society	Prisoner's Dilemma	14	2 × EEG	Results generated from EEG hyperscanning are related to the increased activity in the dorsolateral prefrontal and orbitofrontal areas during the different task phases when compared to the rest state. These cortical activities are specifically larger during the Defect conditions than in the other experimental situations.
Neuroeconomy	Astolfi et al., 2009, 2010a, Conference Proceedings – IEEE Engineering in Medicine and Biology Society	Prisoner's Dilemma	36	2 × EEG	Statistically significant links between homologous cortical areas in the two couples of subjects performing the PD game have been observed in the prefrontal areas of both subjects during the Cooperation condition whereas they are almost absent during the Defect condition
Neuroeconomy	De Vico Fallani et al., 2010, PLoS ONE	Prisoner's Dilemma	52	2 × EEG	It is possible to make predictions at 91% accuracy of the outcome of the decisions of couple of players in the PD game by using indexes estimated on the inter-brains EEG causal relations estimated during the 4 seconds preceding the decision of the dyads
Neuroeconomy	Astolfi et al., 2010b, Conference Proceedings – IEEE Engineering in Medicine and Biology Society	Chicken's Game	38	2 × EEG	A large involvement of the prefrontal regions during the Defect condition is observed when compared to the other conditions
Neuroeconomy	Astolfi et al., 2011, IEEE Intelligent Systems	Prisoner's Dilemma	52	2 × EEG	Estimated interbrain connectivity by using Partial Directed Coherence, suggested an important role of the prefrontal and fronto-orbital regions of both hemispheres in all the experimental conditions examined
Decision-making	Babiloni et al., 2006, 2007 Conference Proceedings – IEEE Engineering in Medicine and Biology Society	"Bridge-like" card game	8	4 × EEG	Results reveal larger activity in prefrontal and anterior cingulated cortex in different frequency bands for the player that start the game when compared to other player
Decision-making	Astolfi et al., 2010c, Brain Topography	"Bridge-like" card game	14	4 × EEG	Results presented suggested the existence of Granger-sense causal relations between the EEG activity estimated in the prefrontal areas 8 and 9/46 of one player with the EEG activity estimated in the ACC of their companion.

Please cite this article in press as: Babiloni, F., Astolfi, L., Social neuroscience and hyperscanning techniques: Past, present and future. Neurosci. Biobehav. Rev. (2012), http://dx.doi.org/10.1016/j.neubiorev.2012.07.006

MODELS FOR SOCIAL INTERACTIONS

Please cite this article in press as: Babiloni, F., Astolfi, L., Social neuroscience and hyperscanning techniques: Past, present and future. Neurosci. Biobehav. Rev. (2012), http://dx.doi.org/10.1016/j.neubiorev.2012.07.006

Temporal synchronization	Cui et al., 2012, Neuroimage	Button press minimizing time difference (cooperation)	22	2 × NIRS	Right superior frontal cortices activity increased during cooperation, but not during competition
Temporal synchronization	Funane et al., 2011, J. Biomed. Optics	Button press minimizing time difference	12	2 × NIRS	Increased between brain covariance of prefrontal cortices during cooperation
Music production, temporal aspects	Lindenberger et al., 2009, BMC Neuroscience	Music production synchronously with the aid of a metronome	16	2 × EEG	Coordinated actions for music production are preceded and accompanied by between-brain oscillatory couplings in the theta frequency band in scalp locations consistent with prefrontal cortices
Music production, emotional aspects	Babiloni et al., 2012, Neuroimage, 2011, Cortex	Execution of a musical quartet piece, successive observation of such performance, rest condition	12	4 × EEG	Increased brain activity in alpha band in right ventral-lateral frontal gyrus (BA 44/45) correlated with the increase of empathy as revealed by psychometric test
Recognition of gesture in engaged couples	Schippers et al., 2010, Neuroimage	Participants in turns have to gesticulate during fMRI acquisition to inform the partner about a particular object or action. Partners successively have to guess (from video recording) the object or action mimicked by the partner	18	1 × fMRI	The activity in the dorsal and ventral premotor, somatosensory cortex, anterior inferior parietal lobule, and midtemporal gyrus (putative Mirror Neural System) and the activity in the ventromedial prefrontal cortex (vmPFC) including the anterior cingulate and paracingulate gyrus of the guesser is Granger-caused by fluctuations in activity in the pMNS of the gesture
Recognition of emotional faces in engaged couples	Anders et al., 2011, Neuroimage	Generation of particular faces associated to a precise emotional feeling	12	2 × fMRI	Emotional face communication elicited arousal response in couple. Measured brain activity elicited the same cerebral network in the couple of subjects, in anterior temporal, insular and somato-motor brain regions
Recognition of eye gaze direction	Saito et al., 2010, Frontiers in Integrative Neuroscience	Follow the other gaze or sustain mutual eye-contact	38	2 × fMRI	Right inferior frontal gyrus was significantly active in the couple of subjects during shared intentional state through eye-contact
Recognition and imitation of hand gestures	Dumas et al., 2010, PLoS ONE	Follow the other's hand movements or propose the own hand movement to the other partner	18	2 × EEG	States of interactional synchrony correlate with the emergence of an interbrain synchronizing network in the alpha–mu (7–12 Hz) frequency band between the right centroparietal scalp regions.
Finger movement synchronization	Tognoli et al., 2007, Proceedings of the National Academy of Sciences of the United States of America	Follow the other's finger movements or propose the own finger movement to the other partner	16	2 × EEG	A pair of oscillatory components (named phi(1) and phi(2)) located above right centro-parietal cortex distinguished effective from ineffective coordination: increase of phi(1) favored independent behavior and increase of phi(2) favored coordinated behavior
Finger movement synchronization	Naeem et al., 2012a,b, Neuroimage, Clin. Neurophysiol.	Follow the other's finger movements or propose the own finger movement to the other partner	12	2 × EEG	A right sided cerebral network in the 10–12 Hz range appears to be involved in integrating the mutual information among the members of a dyad that enables the dynamics of social interaction to unfold in time
Gestual interactions (no hyperscanning)	Redcay et al., 2010, Neuroimage	Interact with a partner outside the scanner in live or video-recorded situation	Two experiments with 16 and 13 subjects	1 × fMRI	During the "Live" interaction, as compared to the Recorded conditions, greater activation was seen in brain regions including the right temporoparietal junction (rTPJ), anterior cingulate cortex (ACC), right superior temporal sulcus (rSTS), ventral striatum, and amygdala
Speech comprehension (no hyperscanning)	Wilson et al., 2008, Cerebral Cortex	Observation and comprehension of a story telling observed in a videotape performed by an actor	24	1 × fMRI	Anterior cingulate and adjacent medial frontal cortex, as well as the posterior cingulate and adjacent precuneus were modulated by the time-varying profile of the audiovisual input being largely deactivated relative to rest condition. Comprehension of the audiovisual inputs involved the activation of a network of bilateral inferior frontal and premotor regions
Movie observation	Hasson et al., 2004, Science	Subjects were scanned while they are watching a movie	5	1 × fMRI	Significant inter-subject correlations of hemodynamic waveforms was revealed in sensory specific cortices, the fusiform gyrus, and the limbic system
Observation and memorization of a movie	Hasson et al., 2008, Neuron	Subjects were scanned when they are watching a movie and 3 weeks later when they remembered it	8	1 × fMRI	Brain regions whose BOLD response is significantly more correlated across subjects during portions of the movie that are successfully as compared to unsuccessfully encoded. These regions include the parahippocampal gyrus, superior temporal gyrus, anterior temporal poles, and the temporal-parietal junction.

Table 1 (Continued)

Research area	Authors, journal, year	Task instructions	Number of subjects	Subjects × method	Results
Movie observation	Jääskeläinen et al., 2008	Subjects that were scanned while they are watching a movie	12	1 × fMRI	Significant frontal-cortical inter-subject correlations between pairs of subjects was obtained in addition those observed in sensory and association areas
Movie observation	Kauppi et al., 2010, Frontiers in Neuroinformatics	Analysis of data from Subjects that were scanned while they are watching a movie	12	1 × fMRI	Several regions within the frontal and temporal lobes show inter-subject correlation predominantly at low frequency bands, whereas visual cortical areas exhibit such correlation also at higher frequencies.

ИЭФБ
РАН

WHAT HAPPENS IN INDIVIDUAL BRAIN

WHEN WE PERFORM COGNITIVE TASKS TOGETHER?

AND WHAT ABOUT CREATIVITY?

Creative activity is understood as activity in which new unusual ideas are generated, thinking deviates from stereotypes and conventional lines, and problematic situations are quickly resolved. (Bekhtereva, 2006; Runco, Jaeger, 2012)

OUR main findings in HYPERSCANNING AND CREATIVITY were summarized in the review

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Russian Text © The Author(s), 2021, published in Fiziologiya Cheloveka, 2021, Vol. 47, No. 1, pp. 104–122.

REVIEWS

Neurophysiological Characteristics of Competition in Skills and Cooperation in Creativity Task Performance: A Review of Hyperscanning Research

N. V. Shemyakina[a], *, ** and Zh. V. Nagornova[a], ***

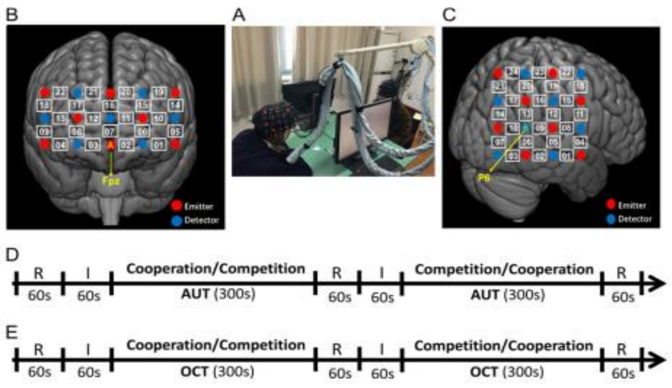
VERBAL CREATIVITY IN DYADS

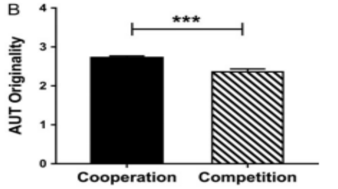
ИЭФБ РАН

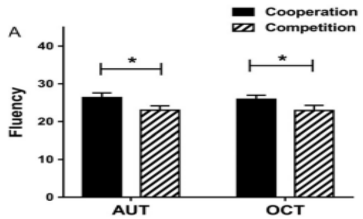
Cooperation Makes a Group be More Creative

Kelong Lu[1], Hua Xue[1], Takayuki Nozawa[2] and Ning Hao[1]

Cerebral Cortex, 2018; 1–14







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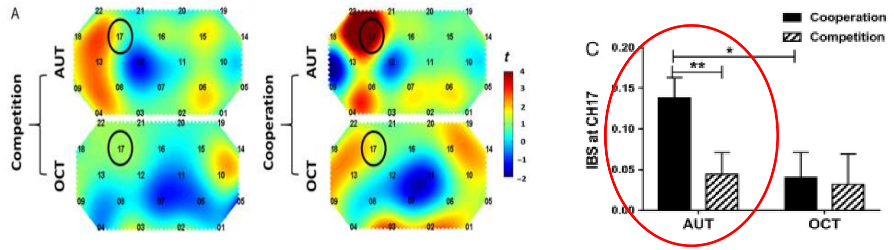
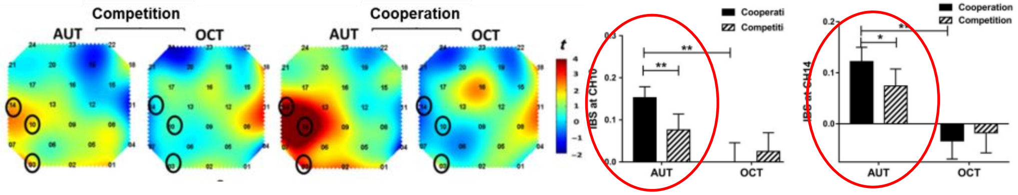
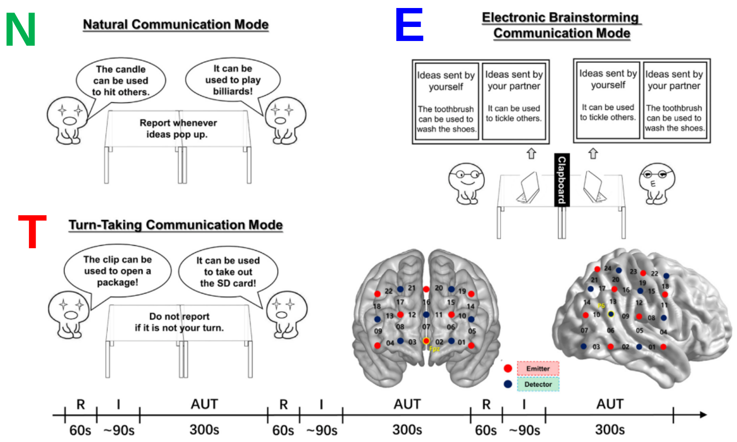


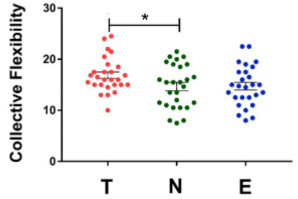
Right temporal–parietal junction (r-TPJ)



Creating while taking turns, the choice to unlocking group creative potential

Kelong Lu[1], Tingting Yu[1], Ning Hao* NeuroImage 219 (2020) 117025





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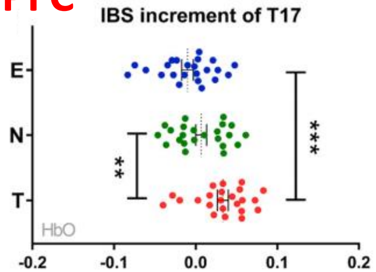
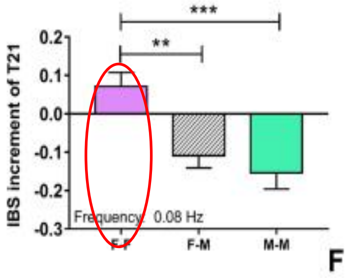
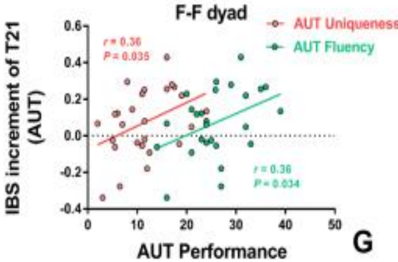


Gender of partner affects the interaction pattern during group creative idea generation

Kelong Lu[1] · Jing Teng[1] · Ning Hao[1]

Experimental Brain Research
https://doi.org/10.1007/s00221-020-05799-7



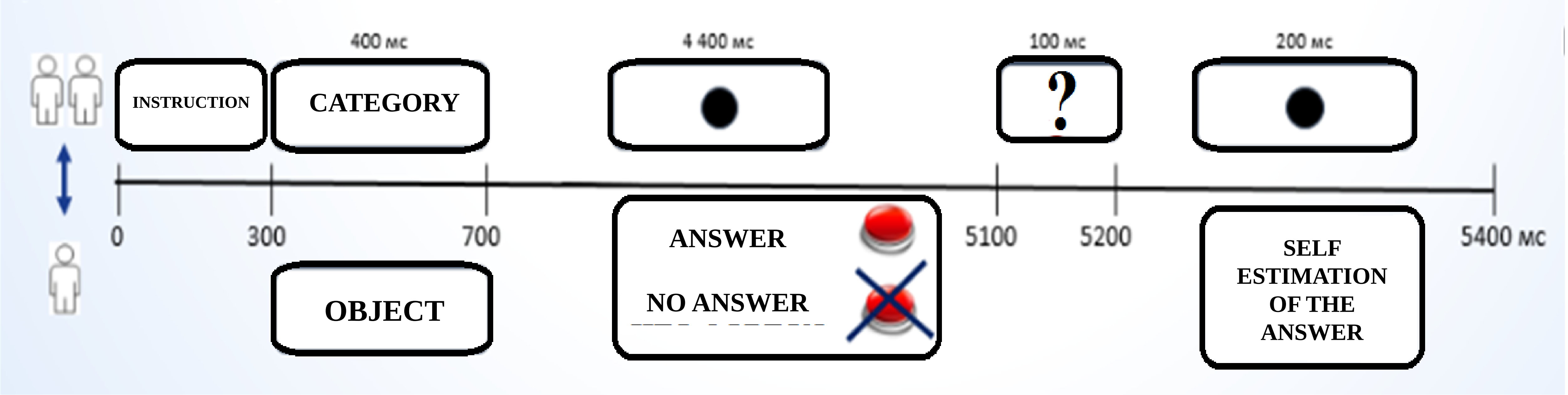


AUT TASKS ORGANIZATION

- ≈10 stimulus x 10 times for each (randomized)

- **CREATIVE TASK:** ALTERNATIVE USES TASK (Guilford, 1961),
Have to find original uses of everyday object, e.g.: brick, paper clip, half hose, paper)

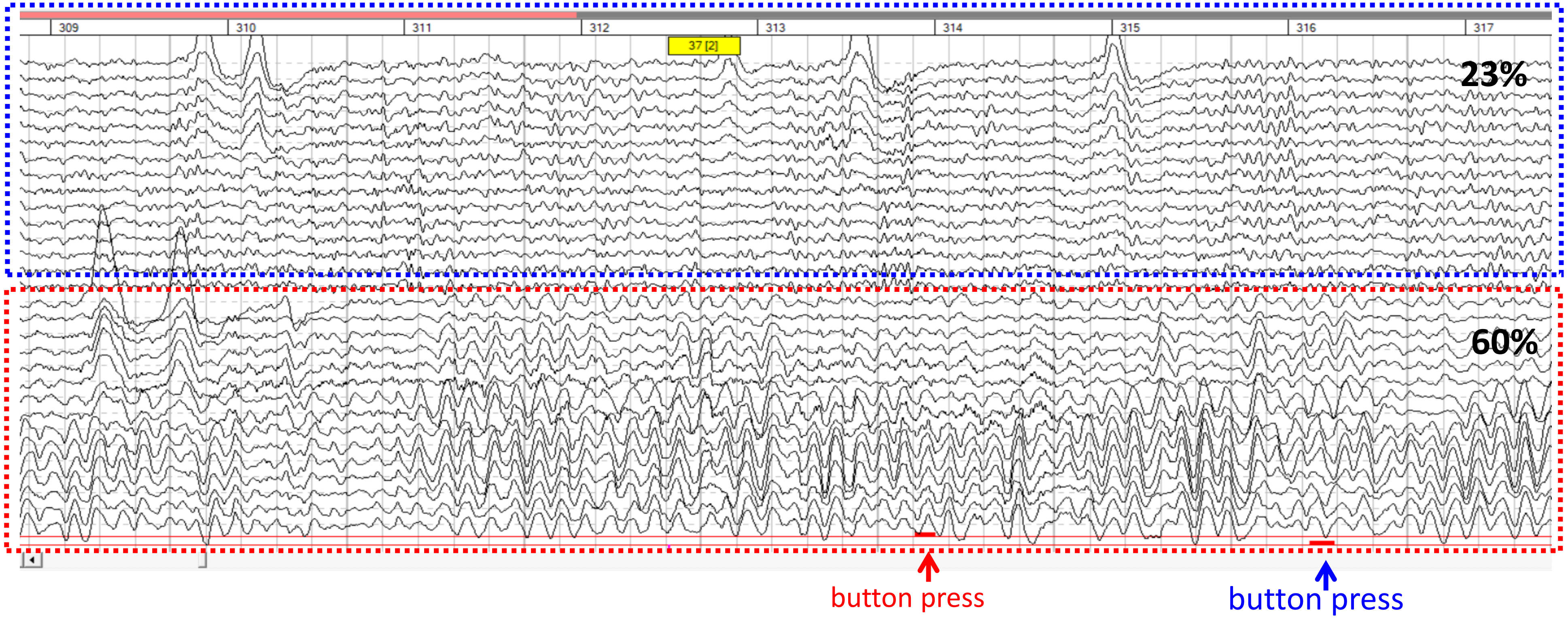
- **CONTROL TASK:** CATEGORY
Have to name objects from category, e.g.: transport, sports, beverages, games)



METHODS

- 44 subject, 18-23 years old (22 dyads, m-m, f-f)
- TASKS performed both individually/in competition (randomized).
- Monopolar EEG (15 channels: Fpz, F7, F3, Fz, F4, F8, C3, C4, T5, P3, Pz, P4, T6, O1, O2), Mitsar-202 (Mitsar, SPb), SR 500Hz, filters: 44-55, 95-105, Gnd ~ Fpz
- Analysis range 1.6 - 30 Гц

DualSounds



ERP DATA ANALISYS

- ICA artifact correction *(Vigario, 1997; Jung et al., 2000; Tereschenko et al., 2009)*
- Artifact rejection *(>100uV, >35 mV in 0-2 Hz and 65 mV in 25-35 Hz, visual inspection)*
- ERPs in competitive and individual performance
- COMPETITIVE and INDIVIDUAL: topography and time interval of differences
- RM-ANOVA for factors STATE (competition/individual) and ZONE (15 channels) in whole brain and in ROI (frontal: Fpz-F8, posterior: C4-O2) with the factor ORDER of performance [Statistica’10].
- The Wilcoxon test for behavioral data

RESULTS

INDIVIDUALLY vs COMPETITION

ИЭФБ РАН

ANSWERS (% from number of trials)

	INDIVIDUALLY		COMPETITION
CREATIVE TASK (AUT)	56% (49-74)	Differed	45% (31-55)
CONTROL TASK (CATEGORY)	87% (82-93)		66% (60-76)

TASK Difficulty (from 1 to 10: min-max)

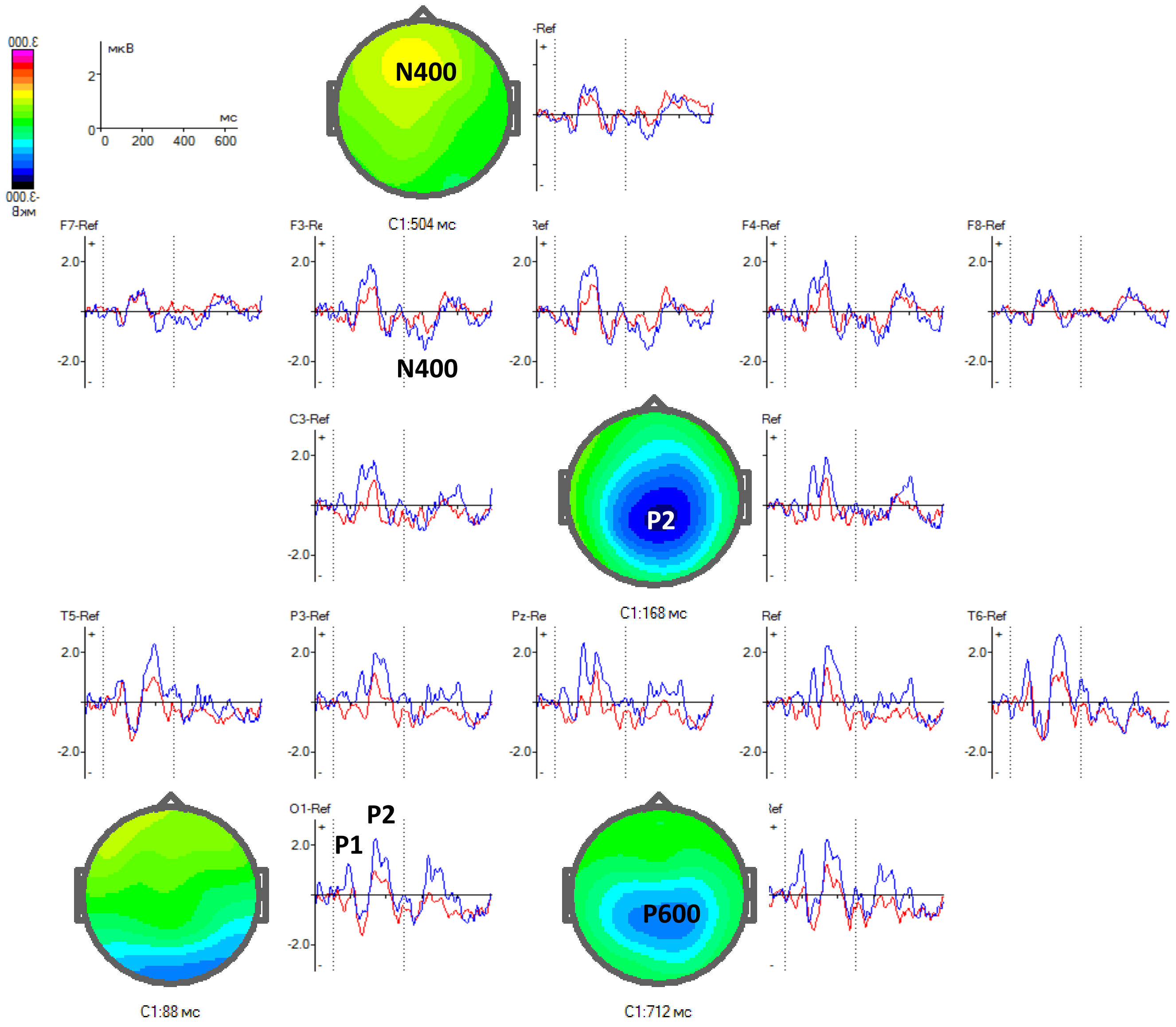
	INDIVIDUALLY		COMPETITION
CREATIVE TASK (AUT)	7 (6-8)	Not differed	6.5 (5.5-7.5)
CONTROL TASK (CATEGORY)	5 (4-6)		4 (4-6.5)

for CREATIVE TASK: Emotions were more positive in competitive condition compared to individual performance ($Z=2.7$, $p<0.01$)

RESULTS

CREATIVE (AUT) TASK

No Influence of the factor ORDER of performance



COMPETITION vs INDIVIDUAL

- **Lower P1 amplitude**

[ROI State: $F_{(1,43)}$=4.6, p<0.05 **in C3-O2**].

- **Lower P2 amplitude**

[State: $F_{(1,43)}$=11.2, p=0.002, StatexZone: $F_{(14,602)}$=5.4, e(G-G)=0.18, p=0.003].

- **Less negative Frontal N400**

[ROI State: F(1,43)=5.7, p=0.02, StatexZone: F(5,215)=5.0, e(G-G)=0.7, p=0.001 **in Fpz-F8**].

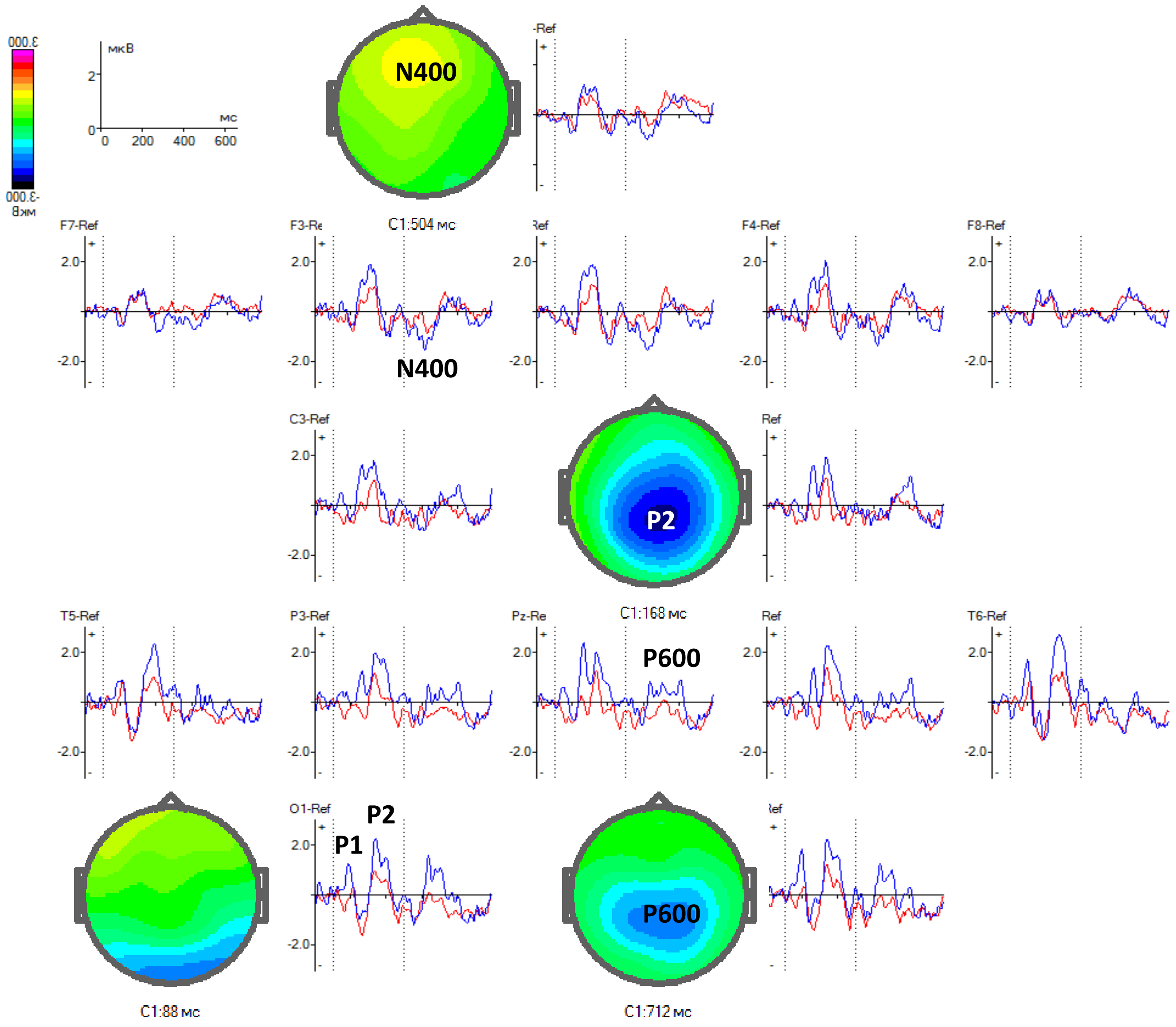
- **Less positive late positivity (P600)**

[ROI State: F(1,43)=6.9, p=0.01, StatexZone: F(8,344)=5.5, e(G-G)=0.5, p=0.0004 **in C3-02**]

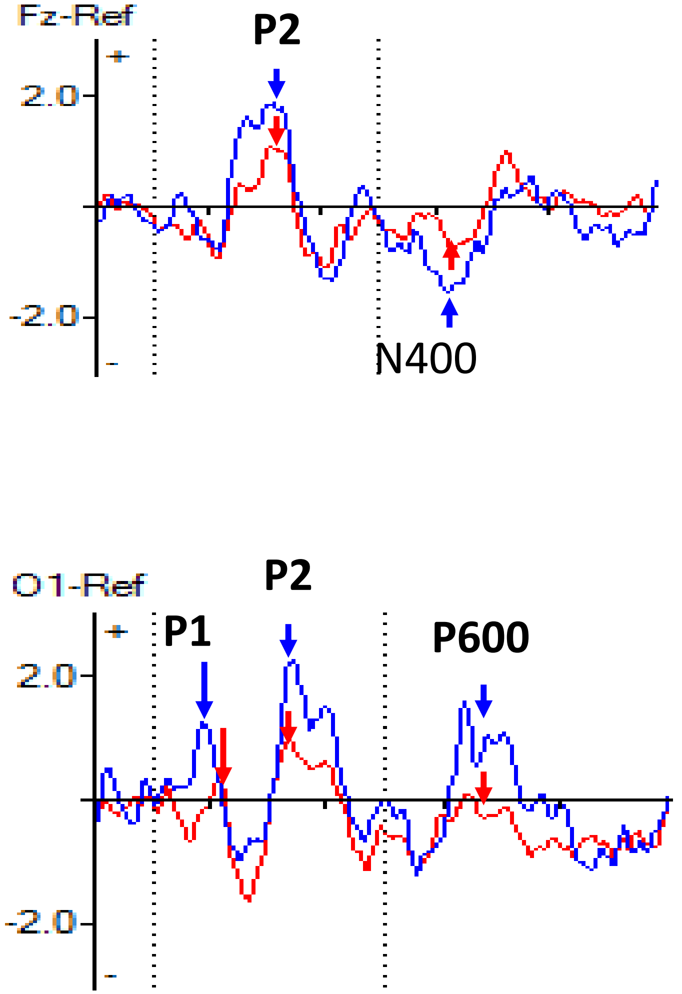
RESULTS

CREATIVE (AUT) TASK

No Influence of the factor ORDER of performance



COMPETITION vs INDIVIDUAL



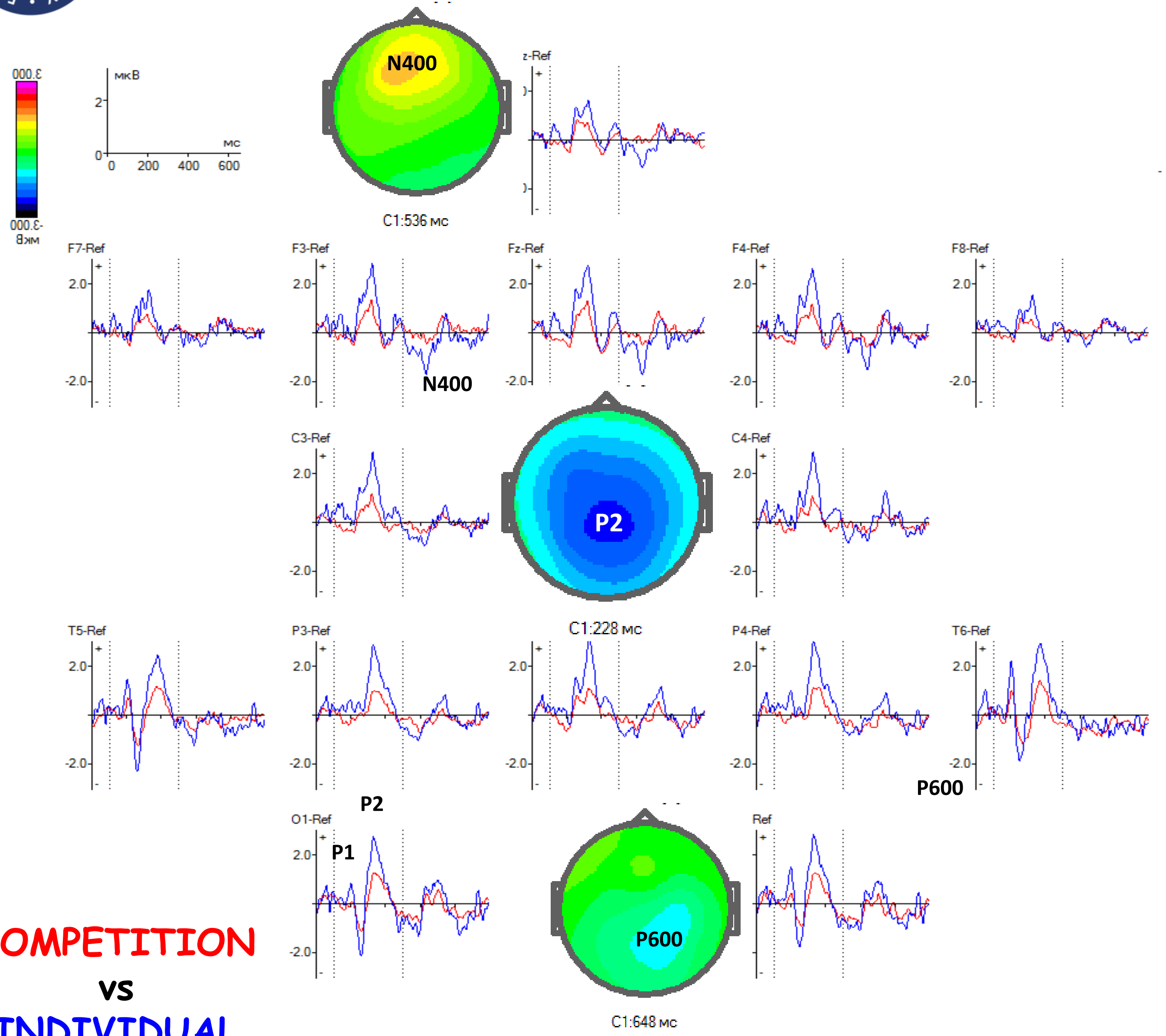
Shift of Latency

RESULTS

CONTROL (CATEGORY) TASK

No Influence of the factor ORDER of performance

ИЭФБ РАН



COMPETITION vs INDIVIDUAL

COMPETITION vs INDIVIDUAL

- **Lower P1 amplitude**

[ROI State: $F_{(1,43)}$=8.8, p<0.01 **in C3-O2**].

- **Lower P2 amplitude**

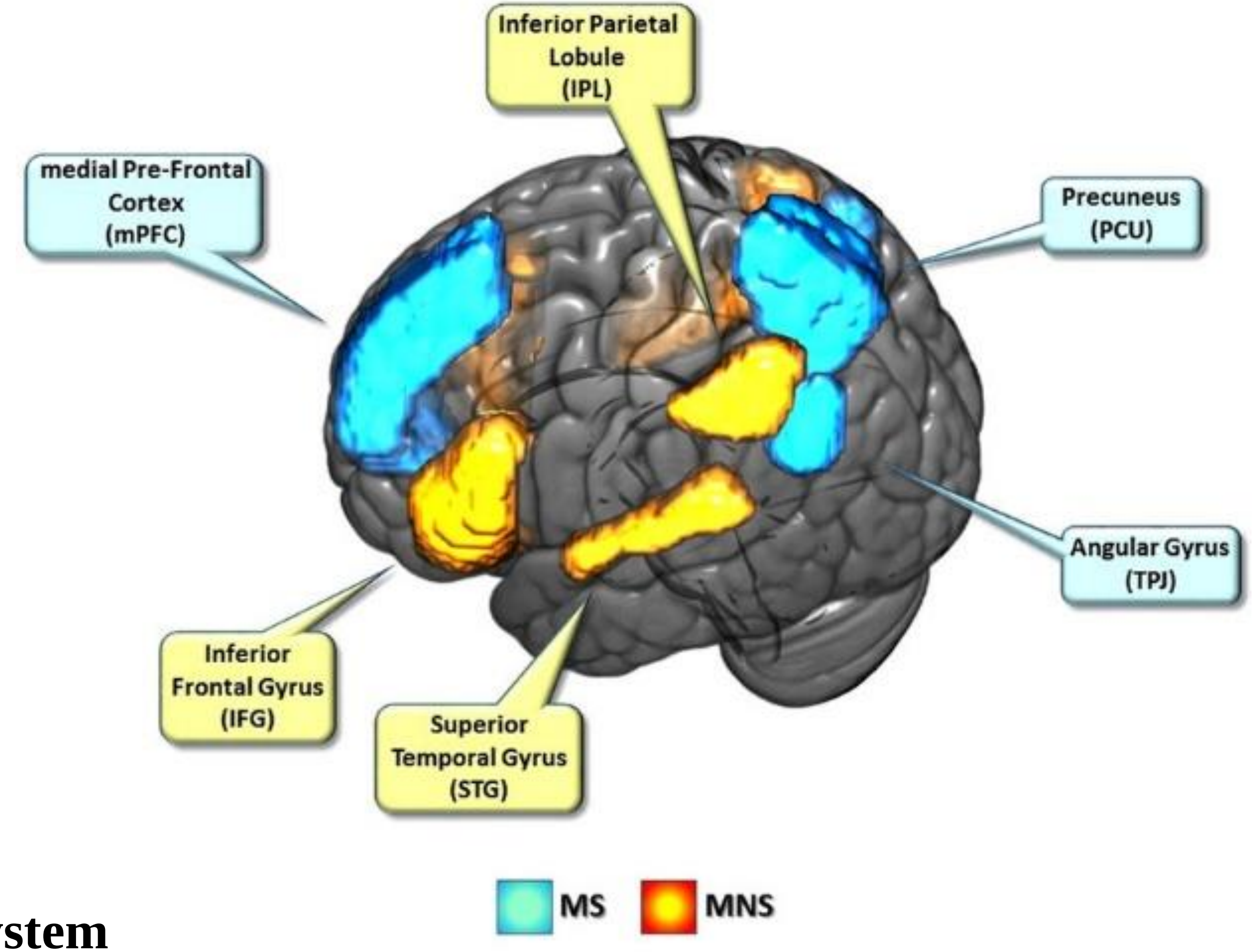
[State: F(1,43)=28.3, p<0.001].

- **Less negative Frontal N400**

[ROI State: F(1,43)=5.1, p<0.05, StatexZone: F(5,215)=6.9, e (G-G) = 0.5, p<0.001 **in Fpz-F8**].

- **Less positive late positivity (P600)**

[ROI F(1,43)=6.9, p<0.05, StatexZone: F(8,344)=5.5, e (G-G) = 0.5, p<0.001 **in C3-02**]



MS **Mentalizing System**

MNS **Mirror Neuron Systems**

Begliomini C, Cavallo A, Manera V, Becchio C, Stramare R, Miotto D, Castiello U. Potential for social involvement modulates activity within the mirror and the mentalizing systems. Sci Rep. 2017;7(1):14967. doi: 10.1038/s41598-017-14476-9.

CONCLUSIONS

- Competition objectively made tasks more difficult and led to a decrease in the percent of answers – in both creative and noncreative tasks
- But subjectively task performance in social interaction led to more positive emotions in creative task and no accompanied by task difficulty changes
- Amplitudes of perceptual ERP components (P1, P2) in social interactions are lower in comparison with individual performance without task ORDER effect that confirm absence of training of fatigue effects
- Semantic-related components (frontal N400, late positivity) are modulated by social context and probably associate with the drawing attention by social cues

Thanks a lot for your attention!

Please, contact Zhanna Nagornova for more results

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