Neural correlates of spatial working memory. The encoding specificity of cardinal and oblique orientations.

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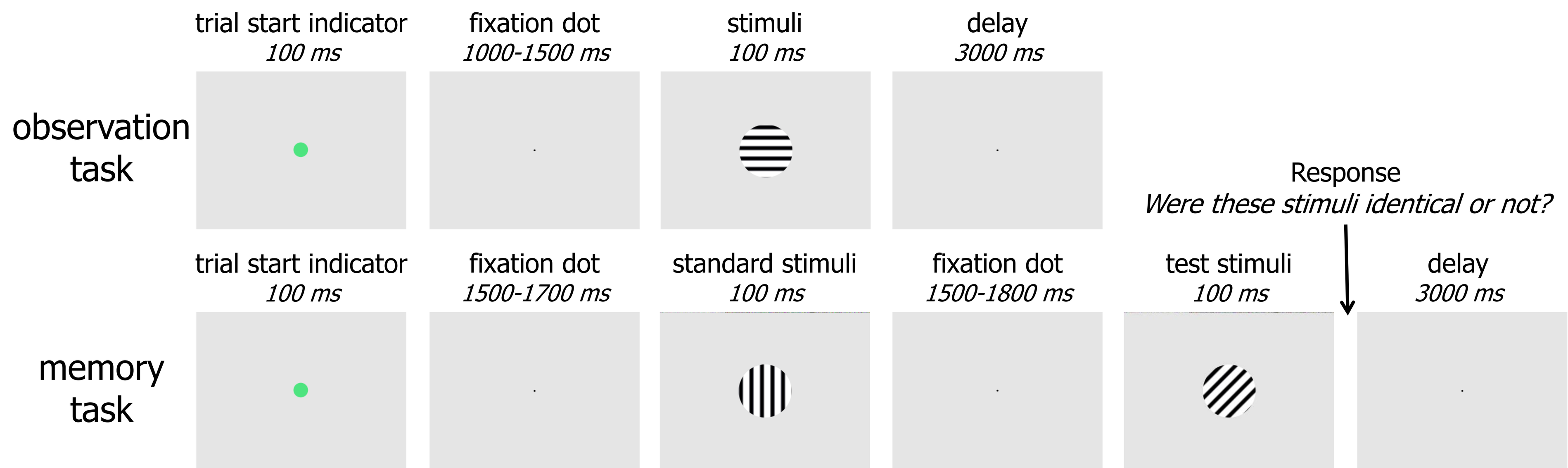
Introduction

The analysis of neurophysiological mechanisms of cardinal and oblique lines identification points out that the prefrontal cortex areas (especially dorsolateral and ventrolateral ones) are engaged in this operation. The orientation sensitivity of these areas might be connected with the necessity of using the external spatial coordinates in spatial working memory. Even in the absence of working memory-dependent tasks, the information about the spatial coordinates may be considered involuntary. In order to examine this assumption the experiments with the spatial working memory model were conducted.

The aim of our study was to identify the features of encoding and retrieval of the information about cardinal and oblique line orientations in the working memory.

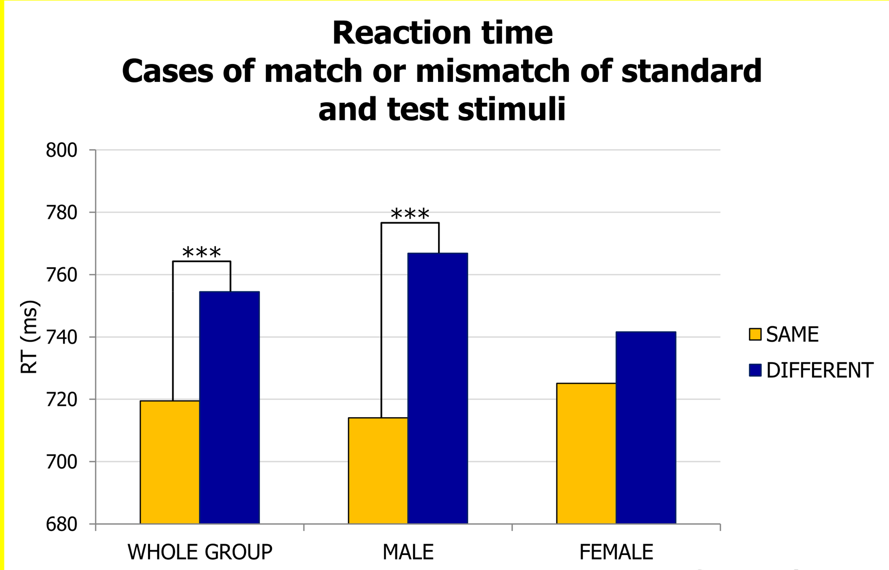
Materials and Methods

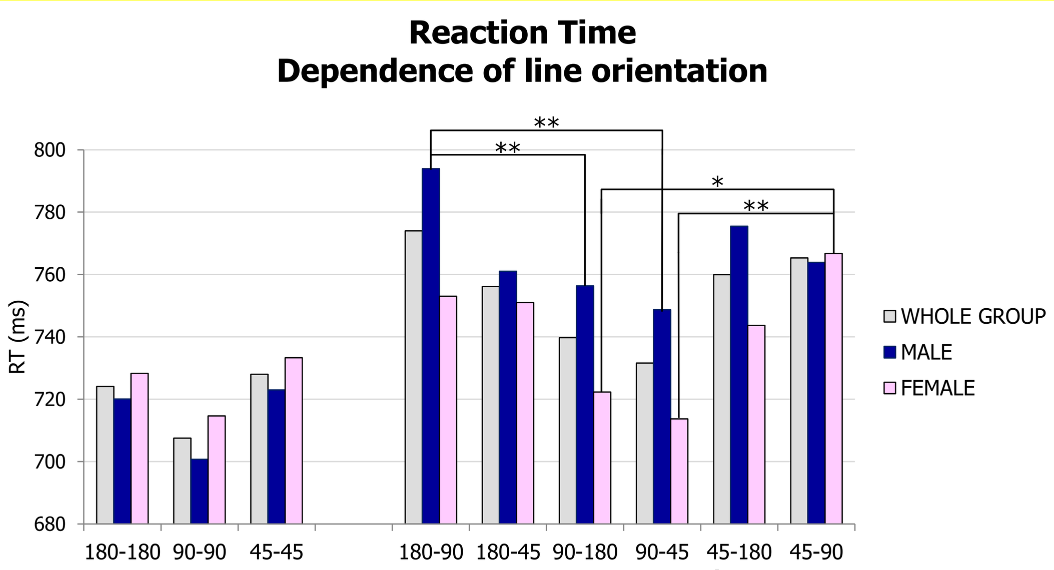
The study involved 41 subjects (20 males) with normal vision. The average age was 22.4±0.5 and 22.8±0.7 for males and females, respectively.



The presentation of stimuli and the registration of recognition accuracy and motor reaction time (RT) was carried out using E-Prime 2.0 *(Psychology Software Tools, Inc., USA)* software. The 128-channel recording of event-related potentials (ERPs) was performed (*Electrical Geodesics Inc., USA*).

Behavioral results



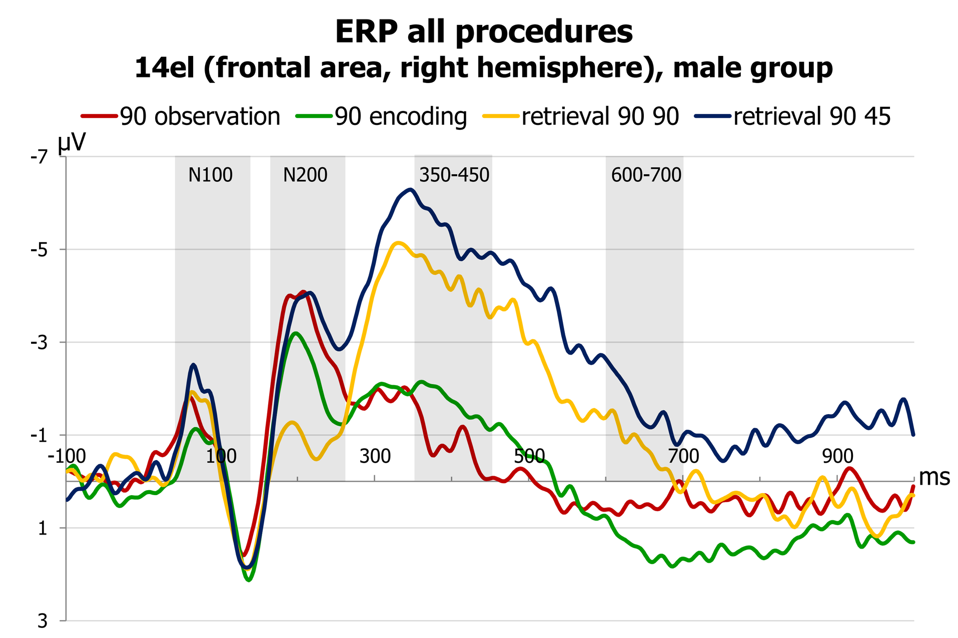


The reaction time (RT) was significantly higher when standard and test stimuli did not match (p<0,001) The increase of the RT in case of mismatch was significantly higher in male group (p<0,001).

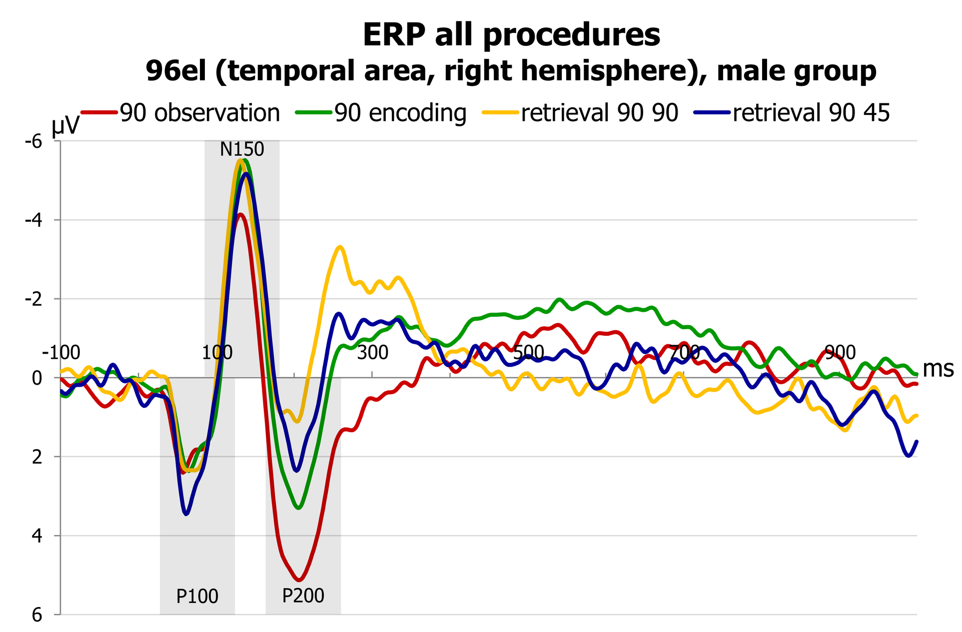
RT depended on the kind of standard stimulus and it was higher for the horizontal (180°) and oblique (45°) gratings than for the vertical (90°) one (p<0,01).

ERPs analysis

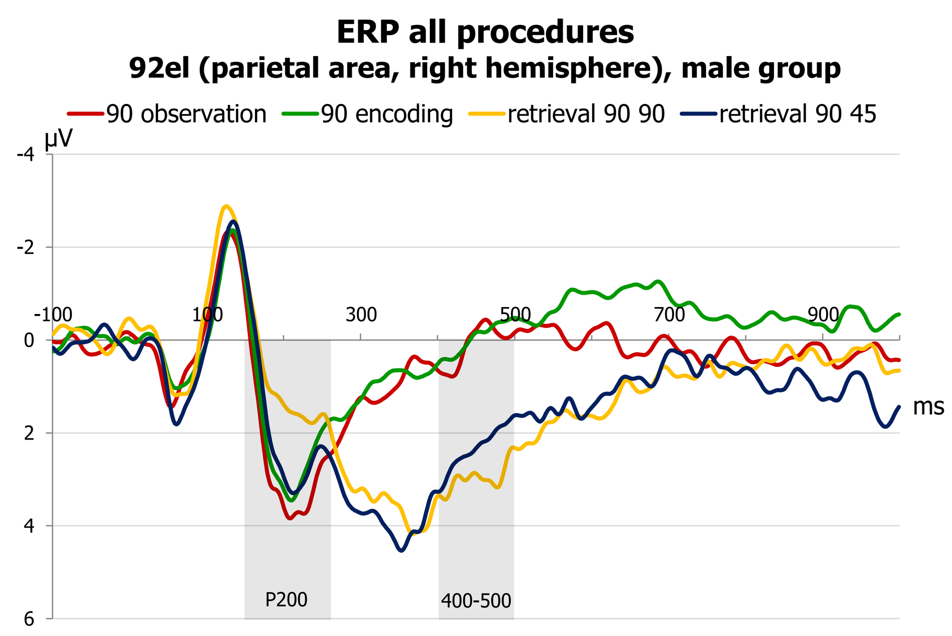
Amplitudes of ERP components were measured in four groups of electrodes (occipital, temporal parietal and frontal) in both hemispheres. The statistical analysis of the amplitude values of the ERP components was executed with the help of ANOVA RM variance analysis with the Newman-Keuls correction for the multiple comparisons.



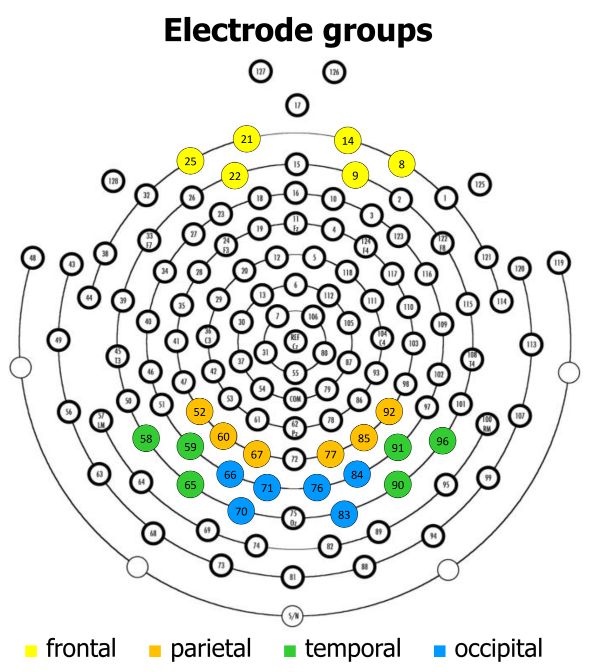
	frontal		
Observation VS Encoding	N100 40-140 ms *amplitude*	Task	F1,15=5,71 p=0.03
	N200 160-260 ms *amplitude*	Task	F1,15=18.91 p=0.001
	600-700 ms *integral square, vertical only*	Task	F1,15=8.30 p=0.01
Encoding VS Retrieval (Same&Different)	350-400 ms *integral square, vertical only*	Task	F1,15=33.85 p<0.001
	400-450 ms *integral square, vertical only*	Task	F2,30=13.19 p<0.001
	600-700 ms *integral square, vertical only*	Task	F2,30=30.47 p<0.001

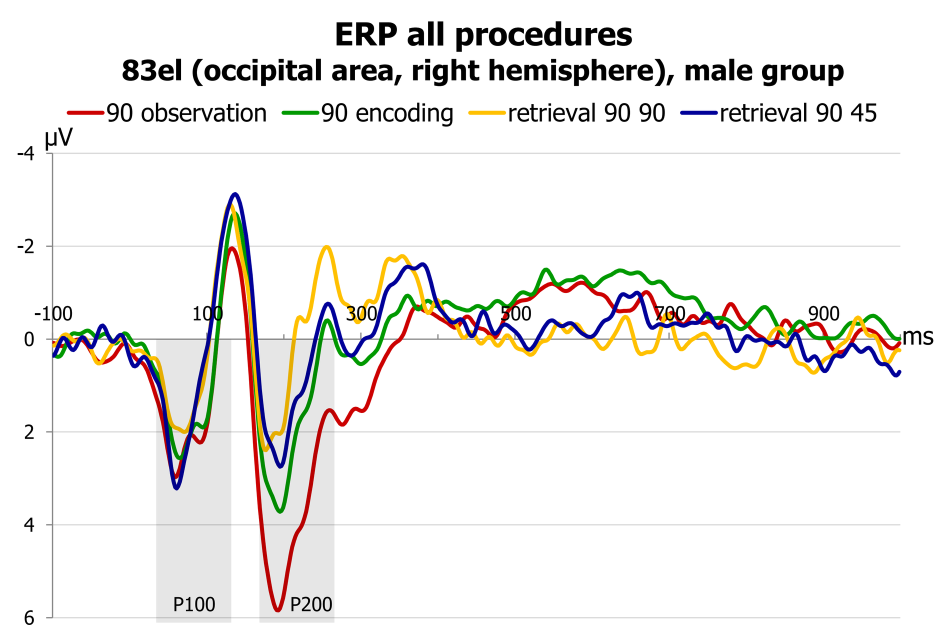


	Temporal		
Observation VS Encoding	P100 *amplitude*	Task	F1,14=4.82 p=0.05
	N150 *amplitude*	Task	F1,14=6.25 p=0.02
	P200 *amplitude*	Task	F1,14=31.49 p<0.001
		Task×Hemisphere	F1,14=8.72 p=0.01



	parietal		
Observation VS Encoding	P200 *amplitude*	Task×Hemisphere	F1,13=8.57 p=0.01
	400-500 ms *integral square, vertical only*	Task	F1,15=14.14 p=0.002
Encoding VS Retrieval (Same&Different)	400-500 ms *integral square, vertical only*	Task	F2,30=8.69 p=0.001

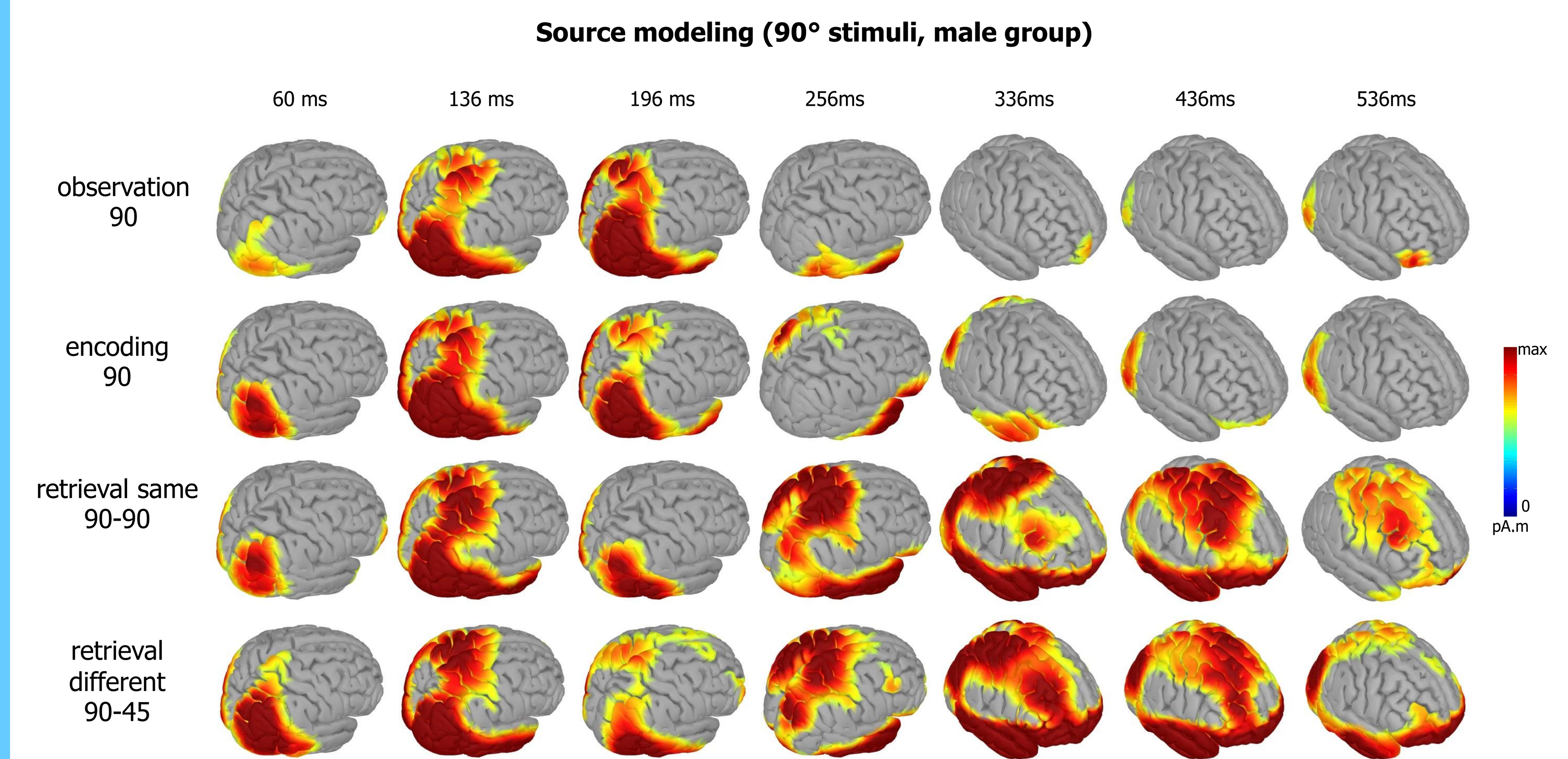




	occipital		
Observation VS Encoding	P100 *amplitude*	Task	F1,14=4,10 p=0.06
	P200 *amplitude*	Task	F1,14=11,84 p=0.004

Source modeling

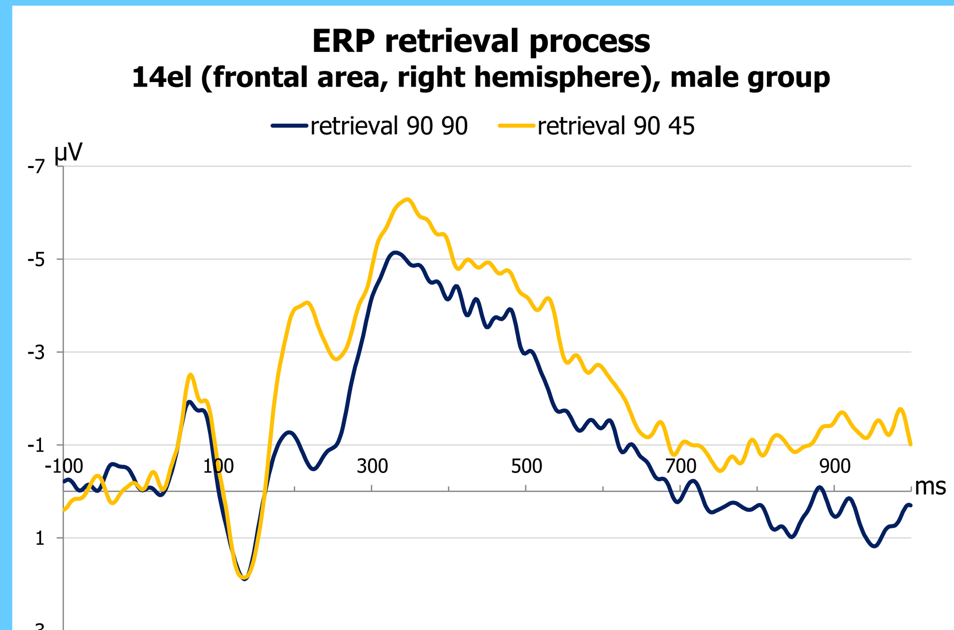
Distributed source modeling was carried out in the Brainstorm 3.2. software (*Biomedical Imaging Group*). We used the wMNE (*weighted Minimum Norm Estimates*) method along with the standard anatomy ICBM 152 (*Fonov et al., 2011*), OpenMEEG BEM head model and standard electrode position.

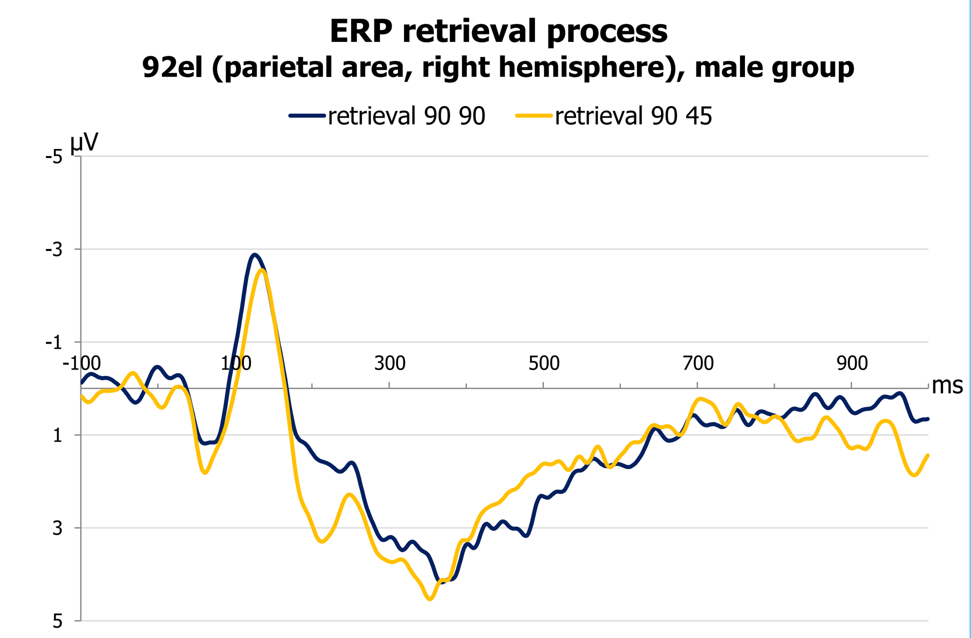


The sources on the early stages of analysis (first 150 ms) differ slightly in their localization in all the procedures.
In the retrieval process we obtained significant differences:

- 200-250 ms time window: much higher involvement of the parietal cortex areas in case of standard and test stimuli mismatch
- after 500 ms: involvement of the occipital and temporal cortex areas, the higher current density in frontal areas in case of standard and test stimuli mismatch.

Special interest





	parietal		
Retrieval Same VS Retrieval Different	N200 (160-260 ms) *amplitude*	Same/Diff	F1,15=15,09 p=0.001
	frontal		
	N200 (160-260 ms) *amplitude*	Same/Diff	F1,15=28.74 p<0.001

Conclusion

The working memory task engages a network of brain regions that includes primary sensory and associative cortices. During the encoding stage the significant differences are detected in the sensory areas for the early processes and in the frontal areas for the very late processes. The retrieval process slightly changes the early stages, but is characterized by high significant increasing of late processes at the frontal and parietal areas. The line orientation has effect only on the early stages of the encoding process at the occipital and frontal areas. The obtained data points out at the regional and temporary specialization of the encoding and retrieval stages of the working memory.

Acknowledgments

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